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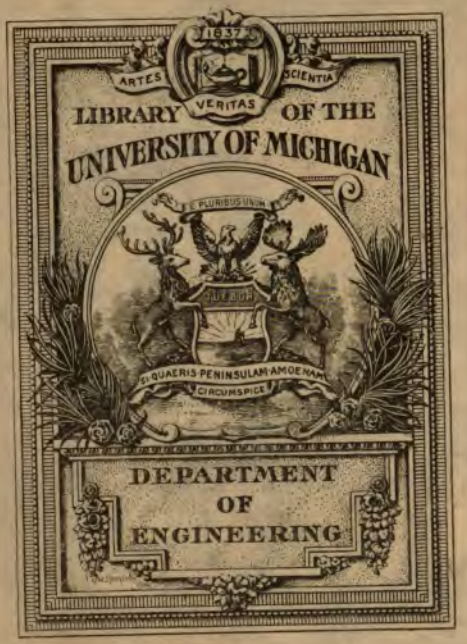
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TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF

IRELAND.

SIXTY-FIFTH, SIXTY-SIXTH AND SIXTY-SEVENTH
SESSIONS, TO MAY, 1901.

VOL. XXVIII.

DUBLIN:
PRINTED FOR THE INSTITUTION
BY JOHN FALCONER, 53 UPPER SACKVILLE-STREET.

1902.

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Reports of Council for 1898, 1899 *and* 1900, *Auditors' Reports and Statement of Accounts for each of the three years ending respectively* 31*st December*, 1898, 1899 *and* 1900.

Revised By-laws as passed and authorised at General Meeting of Members, March 29*th*, 1899.

List of Members for 1901.

198573

[7th December, 1898].

Annual General Meeting.

Mr. W. H. Mills, Past-President, in the Chair.

The Officers of the Institution for the year 1899 were balloted for and duly elected. (See List of Members.)

[29th March, 1899].

General Meeting of Members only, for the purpose of considering the Revised By-Laws.

Mr. W. W. Wilson, President, in the Chair.

The Honorary Secretary read the draft of the By-Laws as prepared by the Council, and respecting which opinion of Counsel had been received—that they were in accordance with the Charter of the Institution. Having stated that a copy of the draft By-Laws had been sent to each Member resident in the United Kingdom, the President enquired if the meeting required any explanation, and in the discussion which ensued Messrs. A. D. Price, G. M. Ross, J. Dillon, F. D. Fletcher, and J. H. Moore took part.

It was then proposed by Mr. P. A. H. Shaw, and seconded by Mr. R. H. Leask, that the By-Laws as prepared by the Council be passed and authorised, and the President, having put the resolution to the meeting, declared it carried.

[17th May, 1899.]

MR. W. W. WILSON, President, in the Chair.

The following candidates for admission into the Institution were balloted for, and duly elected:—

Mr. JOHN PHILIP BERGIN, as Member; Messrs. WILLIAM JAMES PERRIN WAKEMAN, and THOMAS HENRY PILKINGTON, as Associates (non-Corporate).

[6th December, 1899.]

Annual General Meeting.

Mr. W. W. Wilson, President, in the Chair.

The Council intimated that they had transferred Messrs. Wm. Ferguson, Ernest Macartney De Burgh, and Charles Croasdaile Ormsby, from the Class of Associates to the Class of Members; also—Messrs. John Henry Acton, Charles Herbert Ashworth, Robert Samuel Wemyss Barnes, Wm. Fitzgerald Barry, James Delany, J. T. Trevor Dillon, Richard Evans, Cecil Henry Fitzgerald, Thomas Forsyth, Francis Sebastian Gaffney, Wm. Patrick Hade, James Thomas Jackson, Howard McGarvey, Sir George Moyers, George Tighe Moore, John Newbigging, Arthur Wm. Spence, and George Gates Warren, from the Class of Associates to the Class of Associate Members.

The admission of Mr. J. A. Vickery to the Student Class of the Institution, was also announced.

The Officers of the Institution for the year 1900 were balloted for and duly elected. (See List of Members.)

[17th April, 1900.]

SPECIAL GENERAL MEETING.

MR. EDWARD GLOVER, President, in the Chair.

The President having explained the business for which the meeting was called—viz., to adopt the Address approved of by the Council to Her Most Gracious Majesty the Queen on the occasion of her visit to Dublin—and the Honorary Secretary having read a number of letters expressing approval of the object of the meeting from a number of Members, &c.,

The Address was read by the Honorary Secretary, and unanimously adopted as follows:—

To

HER MOST GRACIOUS MAJESTY QUEEN VICTORIA,
QUEEN OF GREAT BRITAIN AND IRELAND, AND
EMPRESS OF INDIA.

MAY IT PLEASE YOUR MAJESTY—

We, the President, Council, and Members of the Institution of Civil Engineers of Ireland, incorporated by Royal Charter, offer our most respectful and cordial welcome to Your Majesty on this auspicious occasion—Your Majesty's visit to Ireland—and assure Your Majesty of our loyal feelings towards Your Majesty's Throne, and Royal Person, and our deep sense of pride and gratification at the felicitous circumstance of Your Illustrious Majesty being once more amongst us. We trust that Your Majesty's stay in this portion of Your Dominions may be as gratifying and pleasing to Your Majesty, as it will be memorable to your subjects, and we pray the Great Architect of the Universe for a continuance of all those Blessings upon

Your Majesty, which have attended your Majesty's Glorious Reign.

Signed on behalf of the Institution of Civil Engineers of Ireland,

[Here follow the names of the President, Hon. Secretary, Hon. Treasurer, and Council.]

The following reply was received:—

Secretary of State,
Home Department.

WHITEHALL,
20th September, 1900.

SIR,

I have the honour to transmit to you by the Queen's Commands, the enclosed reply of Her Majesty to the Address which was presented to Her by the Institution of Civil Engineers of Ireland on the occasion of Her Visit to Ireland.

I have the honour to be, sir,
Your obedient servant,
M. W. RIDLEY.

Edward Glover, Esq.,
President of the Institution of Civil
Engineers of Ireland,
35 Dawson-street, Dublin.

I thank you for the loyal and dutiful Address which you presented to Me on the occasion of My visit to Ireland.

I am much gratified by your loyal and kindly regard towards My throne and Person, and by the cordial welcome which I received.

[2nd May, 1900.]

MR. EDWARD GLOVER, President, in the Chair.

The following Candidates were balloted for and duly elected:—

Mr. ROBERT BARR BELFRAGE, as Member; Messrs. JOHN ALOYSIUS KENNEDY, CHARLES K. DOUGLAS, ROBERT STEPHENSON BARNES, Junr., and JOHN BLAKE, as Associate Members.

SOME NOTES ON WATERWORKS.

By FRED J. DICK, M. Inst. C. E.

IT may be useful to outline the methods adopted in prospecting for and estimating schemes to supply a moderately-sized town with water by gravitation, and in the following brief sketch certain assumptions are therefore made in order that the various stages in the process may be clearly followed by the aid of definite figures based upon the preliminary information which can be obtained from ordnance maps and the use of a pocket hand level and clinometer on the ground, prior to the regular surveys for the purpose of more accurate estimates. In the course of the sketch certain broad principles will be referred to.

Gathering ground areas can be readily ascertained from the one-inch maps, if contoured, aided when necessary by the six-inch survey, but it should be remembered that where permeable strata, at or near the surface watershed line, slope away from the catchment area under consideration, such areas should be deducted, and in the converse case added. An examination of the geological map of the district is essential.

Let us assume that alternative gravitation sources of supply have been in view for more than a year, and that rain gauges have been established in these catchments for that period by the local authority of a town of 20,000 inhabi-

tants, and that two suitable sites for reservoir embankments exist in one catchment of 1,800 acres at a distance of 11 miles; and that only one suitable embankment site exists at the other source at a point where the catchment is 3,000 acres, at a distance of 17 miles from the town. We shall further assume that the stream is 230 feet above the town at the uppermost of the two sites in the first case, and 150 feet in the second; and that two miles from the town is a hill 150 feet higher than the town. Call the first scheme A, and the second B. The comparison of the two schemes begins at the hill two miles out, where the town service reservoir would be. What is called the available rainfall is thus found:—

	Inches. A	Inches. B
One year at new rain gauges	45	40
Gauge at nearest permanent recording station for same year	50	44
Average of say 15 years at nearest permanent recording station	40	33
Probable average of 15 years at new gauges	36	30
Deduct one-sixth to obtain average of three consecutive dry years ...	30	25
Deduct 14 inches for evaporation and absorption	16	11

which is the available rainfall at A and B respectively.

The case A is what may be called a convenient standard for storage calculations, for when the available rainfall is 16 inches, if the works fully utilise the catchment, then 1,000 times the catchment area in acres gives the gallons per day it can supply.

It will be found that the preliminary comparison of these two schemes is a much simpler matter than might

perhaps be supposed, if we are allowed to make a few more assumptions for the sake of clearness.

In scheme A, gradient of river or longitudinal slope of valley above embankment sites, 1 in 60. Mean lateral slopes of valley at embankments, 1 in 8, and above embankments, 1 in 12. Gathering ground somewhat peaty, water turbid in floods, and filtration advisable. Water soft.

In scheme B, 500 acres arable, near reservoir site, and therefore advisable to wholly divert in a byewash channel. Gathering ground otherwise excellent, water moderately soft and pretty clear in floods, and no filtration necessary. Gradient of river, 1 in 70. Valley lateral mean slopes at embankment, 1 in 6, and above that, 1 in 10.

Town population increasing 2 per cent. per annum. May double in 37 years. Advisable to provide storage for a supply to $1\frac{1}{2}$ times present population. $1\frac{1}{2} \times 20{,}000 = 30{,}000 \times 30$ gallons $= 900{,}000$ gallons per day to be capacity of storage scheme to supply the town, apart from compensation water.

The capacities of the reservoirs may then be found as follows:—

SCHEME A.

Available catchment at upper site	...	1,000 acres.
Do. do. lower „	...	800 „

Upper site yields 1,000,000 gallons per day if fully used (having 16 inches available rainfall), therefore according to the almost invariable Parliamentary practice the compensation water would be fixed at 333,333 gallons per day. Use lower site for compensation reservoir.

Capacity of Upper or Town Supply Reservoir:—

900,000 gallons per day
90,000 minimum summer flow of stream.

$810{,}000 \times 180 = 146{,}000{,}000$ gallons $=$
23,300,000 cub. ft. storage required.

Capacity of Compensation Reservoir:—

333,333 gallons per day.
72,000 minimum summer flow of stream.

261,333 × 180 = 47,000,000 gallons =
7,600,000 cub. ft. storage required.

SCHEME B.

Catchment area ...	...	3,000 acres.
Less to be diverted	...	500 „
		2,500 „

Available rainfall is 11 inches.

∴ Available yield is 11/16 × 2,500,000 = 1,720,000 galls. p. d.

∴ Compensation water is 1,720,000 ÷ 3 = 573,000 galls. p. d.

Add town supply	900,000
	1,473,000
Less minimum summer flow	225,000
	1,248,000

1,248,000 × 180 days = 225,000,000 gallons, or
36,000,000 cub. ft. storage required

The height of top water at the three sites may now be found by the formula:—

$$H = \sqrt[3]{\frac{3\,q}{v\,r}}$$

Where q is the storage in cubic feet,

v is the length in which there is a rise of 1 foot in the river,

r is the mean lateral slope of valley a short distance above site of the embankment, that is, r to 1

In the cases we are considering, the heights of top water at the embankments will thus be:—

SCHEME A.

Town Supply Reservoir	...	46 feet.
Compensation Reservoir	...	32 feet.

SCHEME B.

Town and Compensation Reservoir 54 feet

The cost of a storage reservoir is usually to a great extent a function of the gross contents of the embankments, often about 2s. 6d. per cubic yard of the latter.

The height of the embankment in these cases may be taken as 6 feet above top water, to which must be added 2 feet, the further height to intersection of slopes. The heights for contents in these cases will thus be 54, 40 and 62 feet respectively.

Let the inner slope of embankment be S to 1.

Let the outer slope of embankment be s to 1.

Let the mean slopes of valley at embankment be r to 1.

Let the height from bed of stream to intersection of slopes be H feet.

Then contents of embankment $= \frac{(S+s)\, rH^3}{3}$

SCHEME A.

Town Storage Reservoir ($23\frac{1}{2}$ million cubic feet).		
Embankment, 85,000 cubic yards.	2s. 6d. ...	£10,625
Compensation Reservoir ($7\frac{1}{2}$ million cubic feet).		
Embankment, 35,000 cubic yards.	2s. 6d. ...	£4,375
		£15,000.

SCHEME B.

Reservoir (36 million cubic feet).		
Embankment 97,000 cubic yards.	2s. 6d. ...	£12,125

Having thus rapidly arrived at the probable approximate cost of the works at the sources, we may digress slightly to consider a few points connected with storage reservoir schemes.

It is desirable, if circumstances permit, to have a set of

reliable stream gaugings extending over at least six months from spring to autumn. The object of such gaugings is mainly to arrive at the probable minimum flow. Search should be made along the stream for a suitable place to erect the gauge, the daily readings of which can be corrected to the catchment area at site of proposed dam. Further corrections have to be made by comparing the rainfall during the period of the observations with the estimated proportionate minimum rainfall. The comparison of local rainfalls should if possible refer to a considerably longer period than the observed gaugings, preferably from 6 to 12 months prior to the commencement of them.

The gauge should be capable of discharging somewhat more than the normal flow of the stream.

The best form for the gauge is:

The central apex is a right angle. This central portion will record accurately very small discharges. To be quite satisfactory the lowest point should not be below the ordinary level of the water on the downstream side of the gauge. The gauge should be well puddled on its upstream side down to a watertight stratum, and the puddle properly protected from the action of floods.

With a gauge so constructed, if the water be at h feet above the horizontal parts, and d feet be the depth of the vertex of triangle below the horizontal parts, the discharge in cubic feet per min. is $171{\cdot}2\,[(d+h)^{\frac{5}{2}}-h^{\frac{5}{2}}]+214\ L\ h^{\frac{5}{2}}$. L being total length of horizontal parts in feet.

If the water is below the horizontal portion the discharge is $171{\cdot}2\ d^{\frac{5}{2}}$.

It is scarcely necessary to remind engineers that weir gaugings are invariably read at a peg or other suitable mark at a known level at some distance above the actual overfall. The person whose duty it is to observe preliminary gaugings of this nature should be careful each day to see that the weir is undisturbed, free of obstruction, and all in proper order, otherwise the measurements may easily prove of little value.

Stream gaugings become of more importance when the catchment at the proposed source of supply largely exceeds that required for a normal storage scheme, when, in fact, the need for storage diminishes and the minimum summer flow approaches to or exceeds the probable demand.

Of paramount importance in the design of a storage reservoir is the waste weir—its position, length, and the safe height of top of embankment above it. It must be thoroughly capable of discharging floods of a magnitude that may occur only once in a century, at a level which, with a strong wind blowing, shall nevertheless not endanger the safety of the embankment.

The diagram (see Plate) which the writer prepared some years ago exhibits the general value of maximum floods in Ireland so far as known. But it is always desirable to check any given case by independent methods. Thus there is a remarkable exception to the general trend of the curve shown in the case of the Finn river at Stranorlar, where with a catchment of 80,000 acres the probable maximum flood was found to be about 8 cubic feet per minute per acre.

The shape of the rain basin in this case is such that the flood waters reach Stranorlar simultaneously, and this combined with the steep, impervious, rocky formation, accounts to some extent for the exceptionally high flood maximum.

For areas of a few thousand acres or less a flood may be

as much as 30 cubic feet per minute per acre. Maximum floods are often caused by the sudden melting of snow.

Thus in Scheme B, with its catchment of 3,000 acres (and the portion to be diverted should not be deducted in designing the waste weir), suppose the crest of the weir 90 feet in length, and a flood of 30 cubic feet per minute per acre to occur, the depth on the weir would be about 3 feet, which is certainly too much; but on looking at the area of the reservoir we find that it would hold one hour of this flood, rising 3 feet, and supposing none going out, and the height of the flood would therefore probably not exceed 2½ feet. Practically it is desirable to have floods pass off with not more than 24 inches in depth on the waste weir. Danger may in some cases be avoided if after the ground has become saturated, and heavy rain is found to continue, the reservoir be drawn down a foot or more by means of the sluices.

It is occasionally necessary to know with a considerable approach to accuracy what will happen under given conditions of top water level and incoming flood water.

Let. A = area of reservoir in square feet.

Q = incoming flood water in cub. ft. per second.

w = length of crest of weir in feet.

c = co-efficient = 5·1. $(= 0{\cdot}636\sqrt{2g})$.

$C = \frac{2}{3}\, c\, w$.

h = depth running over weir at first, in feet.

q = discharge of weir at first, in cub. ft. per. second.

t = time in seconds.

1). Then if $Q \angle q$, required time to fall x feet

(1).

$$t=\frac{2A}{3Q}\,hyp.\ log.\ \frac{\left\{\left(\frac{1}{2}+\frac{C\sqrt{h}}{Q}\right)^2+\frac{3}{4}\right\}^{\frac{1}{2}}\left\{1-\frac{C\sqrt{h-x}}{Q}\right\}}{\left\{\left(\frac{1}{2}+\frac{C\sqrt{h-x}}{Q}\right)^2+\frac{3}{4}\right\}^{\frac{1}{2}}\left\{1-\frac{C\sqrt{h}}{Q}\right\}}+\sqrt{3}\,tan^{-1}\frac{2C(\sqrt{h-x}-\sqrt{h})}{Q\sqrt{3}\left\{3Q^2+(Q+2C\sqrt{h-x})(Q+2C\sqrt{h})\right\}}$$

The limit of $x=h-\left(\frac{Q}{C}\right)^2$

(2). If $Q > q$, required time to rise x feet is:

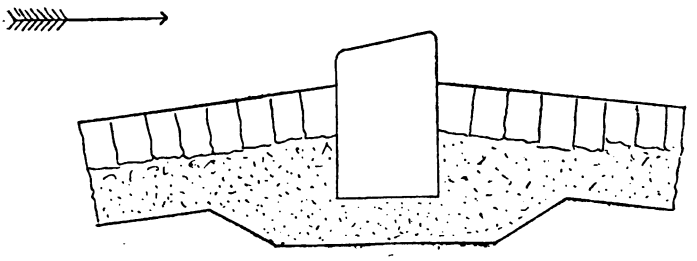
$$(2).\quad t=\frac{2A}{3Q}\,hyp.\ log.\ \frac{\left\{\left(\frac{1}{2}+\frac{C\sqrt{h+x}}{Q}\right)^2+\frac{3}{4}\right\}^{\frac{1}{2}}\left\{1-\frac{C\sqrt{h}}{Q}\right\}}{\left\{\left(\frac{1}{2}+\frac{C\sqrt{h}}{Q}\right)^2+\frac{3}{4}\right\}^{\frac{1}{2}}\left\{1-\frac{C\sqrt{h+x}}{Q}\right\}}+\sqrt{3}\,tan^{-1}\frac{\frac{1}{Q\sqrt{3}}\left\{3Q^2+(Q+2C\sqrt{h})(Q+2C\sqrt{h+x}\right.}{2C(\sqrt{h}-\sqrt{h+x})}$$

The limit of $x=\left(\frac{Q}{C}\right)^{\frac{2}{3}}-h.$

(3). If $q=0$, and $\therefore h=0$, the time to rise x is:

$$(3).\ t=\frac{2A}{3Q}\,hyp.log\left[\left\{\left(\frac{1}{2}+\frac{C\sqrt{x}}{Q}\right)^2+\frac{3}{4}\right\}^{\frac{1}{2}}+\sqrt{3}\,tan^{-1}\frac{-C\sqrt{x}}{\frac{1}{\sqrt{3}}\left(2Q+C\sqrt{x}\right)}\right]_{1-\frac{C\sqrt{x}}{Q}}$$

It may be observed that the masonry crests of weirs are usually made level in cross section, but if it be desired to gauge the water running to waste with some accuracy they would be better if sloped thus:—



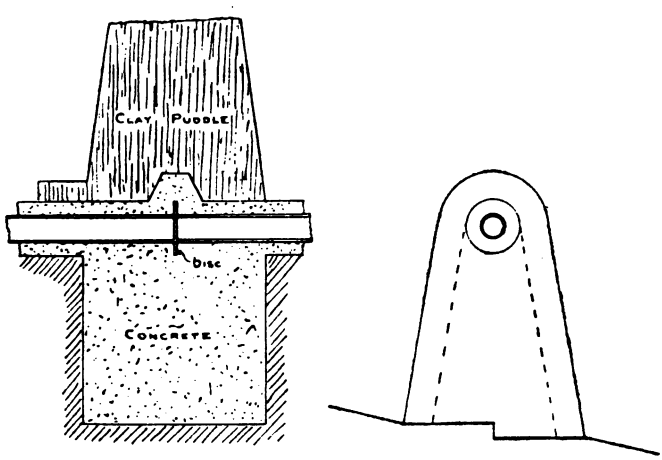
Waste weirs should be placed well in the side of the hill in excavation, and the puddle trench carefully connected to the concrete and other work. There should be deep courses arched upstream to secure the pitching from damage. The waste weir itself is frequently of an arched form on plan pointing towards the reservoir, to save excessive excavation. Sometimes it is placed at right angles to the line of the embankment, and the waste weir channel curved round and gradually narrowed. The waste weir channel should be kept well clear of the outer slopes of the embankment, and be throughout in excavation.

The puddle wall of a reservoir embankment requires the utmost vigilance on the part of both engineers and contractors during its construction. It should be carried down to not less than one foot into the solid rock, clay, or other impervious material. Its bottom width should be one-half that at the surface of the ground. Before the works are designed, not only should proper borings be made along the line of the proposed embankment but trial pits should also be opened both on that line and within the reservoir area, in order to ascertain with certainty the nature of the strata, probable depth and extent of puddle trench, feasibility of getting the requisite earthwork, clay puddle, etc., etc. Valleys selected for storage reservoirs should if possible be water worn ones, and not such as are produced by a considerable geological fault, which may render a watertight dam an impossibility.

The filling in of the puddle trench should be commenced at the lowest level, and be carried on at both ends, so as to have as few joinings as possible, and no part should be filled in until the bottom has been thoroughly washed and cleaned and has been examined and approved by the engineer. The clay should have stones of more than half a pound picked out of it, and should be properly cut, wetted and soured

for not less than 24 hours and then worked up before being put in the trench or puddle wall. It should be put on in 3 inch layers, and then cut with a proper puddling tool, and thoroughly worked and trodden, the one layer into the other, so as to be solid, of uniform consistency, and perfectly watertight. The surface of the puddle should be kept on a level of not less than 6 inches higher than the adjoining portion of the embankment, and should be properly watered and worked up before another layer is put on.

If the outlet pipe (in small catchments of a few hundred acres) or culvert (with larger catchments) crosses the line of embankment, and is not tunneled through the rock in side of hill, the puddle trench crossing should be executed thus:—



Longitudinal Section Cross Section

The concrete work has a feather all round, and all the concrete is battered so that the puddle tends to wedge itself close against it, and in the case of an outlet pipe a cast iron disc should be fixed round it, with usual lead joint, in the midst of the concrete, The object is to prevent

all risk of the smallest creep of water along the outside of the pipe or culvert, as the case may be, up to and beyond the line of the puddle wall, as such would be absolutely fatal to the embankment. Except when under an outlet pipe or culvert, concrete in reservoir embankment trenches is not to be recommended.

The area of a town supply storage reservoir should be stripped of all turf and other vegetable matter, and the same course is adopted with site of embankment.

The embankment should be formed in regular layers not exceeding 6 inches in depth each when spread out, and sloping from the sides down to the centre at an inclination of 1 in 12. The material for the embankment should be got within the reservoir area, but not too close to the embankment. The most clayey part of the stuff got from the excavation should be used for the heart of the embankment, but more especially for the reservoir side, and the more stony gravelly and sandy portions for forming the slopes, but more especially for the outer side of the embankment, and no turf, moss or vegetable matter whatever should be allowed in the embankment. Every layer should be spread out to the proper thickness and pressed or trodden down by heavy carts or barrows to pass over it without rail or planks, which should not be allowed on the embankment, although they may be used in bringing forward stuff to be afterwards laid on by carts or barrows; and if necessary to give the embankment sufficient solidity there should be a heavy roller passed over each layer, and if required, it must be well pounded down by beaters. In any case where stones are laid on the embankment they should be put on in a regular layer, each stone laid on its flattest bed, and no stone nearer another than 4 inches. The next layer should consist of such stuff as will blind and fill up entirely the crevices, and the whole should be made one

compact mass so as not to be liable to subsidence. The stuff used for embanking should be kept thoroughly moistened by having water poured over it.

A matter affecting the security of all embankments, whether reservoir, canal, or reclamation, which have water to hold up, is the treatment of the back or outer slopes. These should be covered by a layer of stones not less than 3 inches thick, broken to 2½ inches ring, and over that there should be 6 inches of soil, turfed or sown with clean rye grass and white clover seeds. The layer of stones is found to prevent the burrowing of rabbits and other animals, and the neglect of this precaution has caused serious accidents on some canals and reclamation embankments.

The inner slopes of reservoir embankments are of course protected by pitching laid on broken stones for a suitable distance down from top water level, the thickness being greatest near top water level, generally 10 to 12 inches, according to the size of reservoir and fetch of waves. The lower portion need only be protected by broken stones. Care is needed with regard to this pitching. The beds and joints should be rather more full at 2 inches below the surface than at the surface, so as to allow of the blinding getting fairly in, and no water worn or rounded boulders should be used.

With regard to the outlet works for town supply the principle is well understood that the water should be drawn off at as high a level as possible, so that several different sluices have to be provided at various heights. In compensation reservoirs this is not necessary. It is desirable to have as much sluicing power as possible available for lowering the water independently of the town or compensation water. The designs of outlet works vary considerably, and they are hardly alike in any two reservoirs ever constructed. The upstand shaft, whether of masonry or cast iron, should

be kept as near the centre of the embankment as possible, especially when there in an outlet culvert leading from it. The masonry should be surrounded by clay puddle, which should be continuous along the outside of the outlet culvert or pipe until it joins the puddle of trench and wall. In compensation reservoirs the upstand shaft may be placed close inside of the puddle wall as leakage through the inlet culvert on the reservoir side is then impossible. Outlet pipes or culverts should be designed to pass the probable heavy flood waters at a moderate head. They should be calculated simply as orifices, and the rest of the pipe or culvert constructed of the same dimensions to the outlet below embankment. The waste weir and its channel should of course be commenced and finished as soon as practicable. The work of inserting the masonry plugs in an outlet culvert is critical, and should be carried out with expedition during the dry season. This masonry must have radiated joints.

In small reservoirs with the embankment not more than 25 or 30 feet or so in height it is usually sufficient to have a cast-iron upstand shaft fitted with sluices and connected to the outlet pipe at its base, standing in a forebay protected by a grating near the foot. In larger works the upstand shaft should be constructed wholly of masonry, and may have single or double chambers according to the special circumstances of the case. The sluices have to be strongly designed. For square wall sluiees, if h = head in feet, and s = length of side in inches, the thickness of the body should be—

$$t'' = 0{\cdot}0128\ s\sqrt{h}$$

And for circular sluices of radius, r inches—

$$t'' = 0{\cdot}018\ r\sqrt{h}$$

the design being reinforced in the usual manner at the

edges, and by the cross stiffening webs, vertical and horizontal to which the sluice-rods are attached. They should in all cases be faced with gun-metal, and slide on gun-metal guide faces. The initial stress to lift such sluices is practically half the pressure upon the sluice plus weight of sluice and rods. This is of importance in designing the sluice-gearing which should be of ample strength. A sluice 2 feet square under a head of 70 feet should have a sluice-rod about $2\frac{1}{8}$ inches in diameter, with the brackets not more than 9 feet apart. Sluice outlets such as those at the culvert plug at foot of upstand shaft should be bell-mouthed, so that the area of the pipe is three-fifths the area of its mouth, the length of the expanded portion being half the diameter of the pipe.

In calculating the power of the lowest sluice to lower the reservoir level by discharging directly into the outlet culvert or the river immediately below the embankment, if A be the area in square feet of the outlet pipe (not its bell-mouth), or sluice in plug which discharges into the culvert; and a be the area of each of n sluices admitting water to a closed upstand shaft, then the depth at which the water will be in the upstand shaft below the reservoir water at any moment will be:—

$$x = \frac{A^2 h}{n^2 a^2 + A^2}$$

h being the height of the reservoir water at the same time above the centre of the outlet sluice.

From this the discharge can be calculated, the head above outlet orifice being $h - x$.

Storage reservoirs have to be contoured, and tables of capacity constructed. Much loss of time and labour may be saved by taking the contours (usually constructed from cross sections) at say every 5 feet in height, and after finding their areas on plan by planimeter, calculating the inter-

mediate areas by the method of second differences—a more than sufficiently accurate method—as follows:—

Let A be the larger area, and a the smaller.

Let n be the number of intermediate areas required.

$$\text{Find } b = \left(2\sqrt{a} + \frac{\sqrt{A} - \sqrt{a}}{n+1}\right)\left(\frac{\sqrt{A} - \sqrt{a}}{n+1}\right)$$

$$\text{And } c = 2\left(\frac{\sqrt{A} - \sqrt{a}}{n+1}\right)$$

Then the intermediate areas can be found by simple addition thus:—

$$a + b$$
$$a + 2b + c$$
$$a + 3b + 2c$$
$$a + 4b + 3c, \text{ \&c.}$$

Diagrams of reservoir capacity and of waste weir discharge should be constructed. In important reservoirs the registration of water heights should be by self-recording clockwork arrangements, and an independent pencil or pen should begin its record when the water is near the waste weir level, on the same drum, but to an enlarged scale and having its own float and mechanism. The latter is for the purpose of obtaining an accurate record of the water flowing to waste. After a few years this will be found invaluable in arriving at the correct yield of the district when the town supply and compensation measurements are added. To check the town consumption a measuring cistern may be connected by a rapidly closing balanced valve capable of shutting off the service reservoir in a few seconds. The rate of descent of a floating gauge in the measuring cistern may then be observed at different hours of the day and night, and the actual rate of consumption ascertained with great accuracy, from special tables or diagrams made for the purpose, and applicable to the measuring cistern in use.

Compensation water is frequently measured by suddenly opening a balanced gap in a cast-iron trough leading across a measuring cistern placed in a convenient position below the embankment, and if the head on the main pipe or aqueduct commences below the storage reservoir, the town supply may be also measured in this manner and situation. Gauge weirs are simpler and less expensive, but do not always meet the special requirements of the case.

But by far the best method of measuring quantities of water delivered for any purpose whatever is undoubtedly the Venturi meter. It is now practically the sole method adopted in the United States, and for simplicity, accuracy, and capacity to deal with large as well as small quantities of water it leaves nothing to be desired.

To revert now to the remaining works involved in the typical schemes supposed, which time compels us to treat as briefly as possible.

The level of low water in the storage reservoir may be taken at say 10 feet (or some similar level) above bed of river at embankment, at which level there is no storage to speak of. The level of top water of town service reservoir or filters will be about 5 feet above the ground probably.

The ruling gradients are therefore:—

A. (240–155) in 9 miles = 1 in 560.
B. (460–155) in 15 miles = 1 in 260.

The quantity is 900,000 gallons per day, or 100 cubic feet per minute (allowing for $1\frac{1}{2}$ times present population).

$\therefore$ $Q\sqrt{G}=(A)$ 2360, and (B) 1810. Corresponding to 12 inch and $10\frac{1}{4}$ inch pipes respectively. These diameters would deliver the estimated quantity after the lapse of about 10 years probably. At first they would deliver fully 10 per cent. more. After the lapse of about 30 years, how-

ever, they would only deliver about the equivalent of 11 inch and 9½ inch diameter pipes respectively. It is, therefore, advisable to increase the diameters to 13 inch and 11 inch respectively, because long main supply lines of pipes should be designed to be fully effective for 30 years.

There is another consideration, however, which here occurs. The storage part of the scheme was estimated for 1½ times the present population only, because storage or sources of supply or both can usually be augmented without difficulty when need arises. But it is often sound policy owing to the comparatively small difference of cost to make the main from the source as far at least as the town service reservoir of somewhat greater carrying power. In the cases we are considering, if double the present population be considered as the proper element for the design of the mains, the quantity would be 133 cubic feet per minute, and the mains would be 14 inches and 12 inches in place of 13 inches and 11 inches.

Let. Q = cubic feet per min.
G = length in which fall of unity in the ruling gradient.
d = internal diam. of pipe in inches.

Then $Q\sqrt{G} = 4{\cdot}7\ d^{\frac{5}{2}}$. (Leslie's formula).

Tables are constructed of the right hand portion of the equation for different values of d, and the discharges are readily obtained by dividing the pipe numbers on the Gravet slide-rule by the square root of what for brevity's sake is called the gradient, although it is really the denominator of the gradient having unity as numerator. From ½ inch to 1 inch should always be added to the diameter thus found to allow for the diminished discharging power of the pipes after 30 years or so, due to the effect of incrustation.

The next point to consider is the thickness of the pipes. The principle on which this is ascertained should be:—Firstly, that the proof test to which the pipes are sub-

jected at the manufacturers' works (in the presence invariably of a properly qualified inspector) shall not cause a tensile stress greater than that at which permanent set commences which is for cast-iron about 1 ton per square inch; and secondly, that the maximum static pressure to which the pipes can be subjected when laid shall not exceed about two-thirds of the proof stress.

The exception is that when the proof-test head thus found would give a thickness less than the minimum at which it is practically desirable to cast pipes of a given diameter, in such cases the proof test for the actual thickness will often greatly exceed 50 per cent. above the maximum static pressure when laid.

The practical scale of *minimum* thicknesses is somewhat as follows:—

DIAM.	THICKNESS.	PROOF TEST, producing stress 1 ton per sq. in.
Inches.	Inches.	Feet.
3	$\frac{3}{8}$	1200
6	$\frac{7}{16}$	750
9	$\frac{1}{2}$	575
12	$\frac{9}{16}$	500
18	$\frac{5}{8}$	360
24	$\frac{11}{16}$	300
30	$\frac{3}{4}$	260

If h be the head at the proof test, in feet
d internal diameter in inches.
the formula for the thickness of pipes should therefore be

$$t = \cdot 000097\ h\ d$$

Pipes should be cast of uniform thickness with only a very small margin of difference in thickness permitted. They are cast vertically, faucet downwards, under a head which is afterwards cut off. While under the proof test they should be struck with a hammer. Pipe calipers, steel

straight edges, and internal and external rings should be used in gauging the accuracy of pipe castings.

In the cases before us, if the maximum static pressure at valley crossings be for A, 350, and for B, 500 feet, the thicknesses of the respective mains at these places will be calculated on corresponding proof-test heads of 525 and 750 feet, giving for the greatest thickness of the 14 inch pipe of Scheme A, $\frac{3}{4}$ inch; and for the 12 inch pipe of Scheme B, $\frac{7}{8}$ inch.

The thickness of the pipes for Scheme A will therefore vary from 9-16th inch to $\frac{3}{4}$ inch; and for B, from 9-16th inch to $\frac{7}{8}$ inch; averaging say, (A) $\frac{5}{8}$ inch, and (B) $\frac{3}{4}$ inch.

The pipe lengths will be 9 feet.

The cost of the mains will therefore be:—

$$(A)\ \frac{9 \times 5280}{9} \times \frac{100{\cdot}45\ (14+\frac{5}{8})\ \frac{5}{8}}{2240} \qquad \text{at say } £5 = £10{,}800$$

$$(B)\ \frac{15 \times 5280}{9} \times \frac{100{\cdot}45\ (12+\frac{3}{4})\ \frac{3}{4}}{2240} \qquad \text{at say } £5 = £18{,}800$$

The cost of carting, laying and jointing with 10 per cent. lead, and 90 per cent. turned and bored joints will be about:—

(*A*)	9 × 1760 lin. yds.	4/6	£3,600
(*B*)	15 × 1760 lin. yds.	4/-	£5,300

Adding 5 per cent. for air, scour and stop valves and other special works, and say 6d. per lineal yard for wayleave, the cost of the mains to Town Service Reservoir will thus be:—

(A)	...	...	...	£15,500
(B)	...	...	...	£26,000

Pin-hole air-valves, screwed into air-vessels or occasionally into inverted belly pipes, are the most satisfactory. They are easily inspected, and are not given to causing shocks to the pipes, as some automatic ball-float air valves do. Scour valves should be from $\frac{1}{3}$ to $\frac{1}{2}$ the diameter of the main, according to circumstances.

In Scheme A filtration is advisable. But as the storage reservoir in this case acts to some extent as a subsiding pond, a rate of 6 inches per hour filtration will probably be sufficient. Where water requiring filtration is taken directly from a river a lower rate of filtration is advisable, Filters can easily be added to, and, except with regard to land, it is unnecessay to provide for more than the immediate probable requirements, which for 20,000 people at 30 gallons would be 600,000 gallons per day, or 96,000 cubic feet, and this divided by 12 feet (per 24 hours) gives 8,000 square feet, or sav 900 square yards of filtering area required. This may be conveniently divided into 3 filters of 300 square yards each, and one additional, filter of that area should be added to provide for sandwashing. Therefore, 1,200 square yards are required, and this at 45s. gives cost of filters alone for Scheme A, £2,700. Filters should have not less than between 5 and 6 feet total depth of water, of which about two-thirds may be occupied by the layers of graded material necessary to support the real filtering material, which is practically the ½ inch thick upper surface of the sand, which should be sharp river sand. The reason for the depth of water mentioned is that with a less depth the water becomes too warm before delivery into the clear water town service reservoir.

Town service reservoirs should hold at least half a day's supply, so as to allow for the variation in demand during the forenoon, plus whatever additional capacity may be judged necessary to allow for time to deal with occasional repairs to the main from the storage reservoir. In some cases there may be a week's supply or more at the site near the town, in a cutting and embanked reservoir, adjacent to which may be the filters and the half day's capacity clear water tank.

Owing to the relation of proposed pipe proof-tests to the

stress produced in the cast-iron and to the subsequent maximum static heads in the work, it would be unnecessary to provide in either of the Schemes instanced more than 1 day's supply calculated on $1\frac{1}{2}$ times the present population—viz., 900,000 gallons, or 144,000 cubic feet, which at $7\frac{1}{2}$d. gives £4,500 as the probable cost of Town Service Reservoir, including all accessories. Smaller service tanks generally cost about 1s. per cubic feet of storage.

There remains the distribution system. The Service Reservoir is 2 miles from the centre of the town; but the most distant point of supply may be 1 mile further off, and on ground 50 feet higher than centre of town. The ground at Service Reservoir being 150 feet above the town, the bottom of tank will be about 142 feet above the same, or 92 feet above highest ground. But the water must be delivered 50 feet above ground level. Hence the ruling gradient from service tanks will be $42 \div 3 \times 5280 = 1$ in 377. The forenoon draught being at double the rate of the average daily consumption (it is sometimes more than that) the main from service reservoir to the first branch will have to be capable of delivering at the rate of 1,800,000 gallons per day, or 200 cubic feet per minute, $200 \times \sqrt{377}$ gives a $14\frac{5}{8}$inch pipe. The main as far as the first branch should therefore be a 16 inch one. The cost of the distribution system would be somewhat as follows:—

Say	$1\frac{1}{2}$	miles,	16	inch,	$\frac{9}{16}$	inch thick,	incl. laying, &c.,	@ 23/-	p. lin. yd.	£3,000
,,	$\frac{1}{2}$	,,	13	,,	$\frac{9}{16}$	,,	,,	,, 19/-	,,	850
,,	1	,,	10	,,	$\frac{1}{2}$	,,	,,	,, 13/-	,,	1,150
,,	1	,,	9	,,	$\frac{1}{2}$	,,	,,	,, 12/-	,,	1,050
,,	1	,,	8	,,	$\frac{1}{2}$	,,	,,	,, 10/6	,,	900
,,	1	,,	6	,,	$\frac{7}{16}$	,,	,,	,, 7/6	,,	650
,,	4	,,	4	,,	$\frac{3}{8}$	,,	,,	,, 4/6	,,	1,600
,,	2	,,	3	,,	$\frac{3}{8}$	,,	,,	,, 3/6	,,	600
										£9,800

The Schemes therefore stand as follows:—

	A	B
Reservoirs	£12,000	£9,700
Pipe to Service Reservoir	15,500	26,000
Filters	2,700	Nil.
Service Reservoir ...	4,500	4,500
Distribution ...	9,800	9,800
Land at £60 per acre	4,300	3,400
	£48,800	£53,400

Scheme B has a somewhat better water, and has, moreover, the advantage that its storage—as the catchment is not fully utilised—can be readilv increased when necessary, by raising the embankment, which may at a comparatively small additional cost be prepared for such a contingency by increasing the top width on the reservoir side of the puddle wall. Outlying villages may apply for a water supply, thus at some future time increasing the population to be supplied; with which and other contingencies, as will have been observed, the main pipe from the reservoir is already capable of dealing to a considerable degree.

Time does not permit of reference to other numerous interesting details which occur in practice, but it is hoped that this brief outline of the processes involved in deciding upon and designing a gravitation scheme may serve to suggest points for discussion.

THE HONORARY SECRETARY read the following remarks which Mr. Wm. Kernaghan had contributed upon the paper:—

(1.) RAINFALL.

Half-an-inch of rainfall falling in January would give a reservoir more than 1 inch falling in May. Very roughly

it may be said the mean British rainfall is one-tenth of an inch per day.

The average rainfall in Ireland during 19 years, 1860–1879, at stations in Waterford, Kilkenny, Armagh, and Antrim, was 38·01 inches. The average for the same stations in the very dry year 1887 was 24·71 or 35 per cent. less than the average.

On five stations on Bradford Waterworks the average rainfall from January to June was 19·88. The average for the same station in 1877 was 9·31 or 53 per cent. less than the average.

(2.) Evaporation and Absorption.

Mr. Dick allows 14 inches.

Experiments at Otterburn Waterworks, near Shawford, Herts. Greatest evaporation in one day in July, 0·24 in.; least in one day in July, 0·03.

Total evaporation from Reservoir, 20·83 inches in the year	July	3·64	January +	0·17
	August	3·33	February —	0·58
	September	2·13	March	1·52
	October	1·03	April	1·92
	November	0·22	May	3·03
	December	0·02	June	3·24
		10·37		10·46

The amount of evaporation on land surfaces in this country varies from 8 to 20 inches.

The evaporation on large water areas is in most cases equal to the rainfall; therefore, in estimating the yield of a watershed or catchment the area of the lake or reservoir should be excluded. The evaporation from Lough Allen, the head lake of the Shannon, during six weeks' dry weather in summer of 1891, in which the lake was closed, was one-eighth of an inch per day.

In the evidence before the Royal Commission on Metro-

politan water supply, 1893, the percolation through three feet of soil with grass growing on surface at Nash Mills and Lea Bridge was 25 per cent. of the rainfall.

(3.) Minimum Flow.

The average summer flow of watersheds, with rocks of medium absorbing power and steep slopes, does not, as a rule, exceed 3·12 gallons per second per 1,000 acres.

In A scheme the 90,000 gallons per diem minimum flow equals 1 gallon per second per 1,000 acres nearly.

(4.) Floods.

Reservoir	Gals per second per acre	Cubic ft. per second per acre	Cubic ft. per min. per acre	Rate of rainfall in 24 hours
Woodhead (Manchester Corporation) - - - -	3·12	0·50	30	12 inches
Vartry (Dublin Corporation) -	3·20	0·50	30	12·22 „

Mr. Dick gives for areas of a few thousand acres, 30 cubic feet per minute per acre, exactly the same as above.

Mr. Symons gives a diagram of maximum rainfalls in the 1888 number, and concludes the following:—

	Inches
A—Common	0·65 in 1 hour
	0·85 in 2 hours
B—Not unusual	1·10 in ½ hour
	1·80 in 1 hour
	2·20 in 2 hours
C—Exceptional	3·10 in 1 hour 40 mins.

(5.) Waste Weir.

In designing the waste weir the length will depend on the average slope of the ground, nature of ground, and whether open or wooded, and intensity and duration of rainfall in flood.

Ziegler gives the following formula for finding the rate of approach of floods:—

Where Q = cubic feet per second per acre.
S = slope in feet per 1,000 feet.
I = inches of rainfall in one hour.
A = area of catchment.
C = a co-efficient in this case taken at 0·62.

Then $Q = 0{\cdot}62 \times I \sqrt[4]{\frac{S}{A}}$

Ziegler gives his average heaviest rainfall from $1\frac{3}{4}$ to $2\frac{3}{4}$ inches in 1 hour. Symons, $1\frac{3}{4}$ inches in 1 hour to $2\frac{1}{4}$ inches in 2 hours. Let us take an extreme fall at $2\frac{1}{2}$ inches in 1 hour.

Mr. Dick gives the fall of the river 1 in 70; valley lateral mean slopes 1 in 10; the general average slope of the ground lies between these grades.

If S = 1 in 50.

$$Q = 0{\cdot}62 \times 2{\cdot}5 \sqrt[4]{\frac{20}{3{,}000}}$$

Q = 0·434 c. feet per sec. per acre = 26·04 c. feet per min. per acre.

If S = 1 in 30.

$$Q = 0{\cdot}62 \times 2{\cdot}5 \sqrt[4]{\frac{33}{3{,}000}}$$

Q = 0·496 c. feet per sec. per acre = 29·76 c. feet per min. per acre.

If S = 1 in 20.

$$Q = 0{\cdot}62 \times 2{\cdot}5 \sqrt[4]{\frac{50}{3{,}000}}$$

Q = 0·558 c. feet per sec. per acre = 33·48 c. feet per min. per acre.

From this it would seem that the 30 cub. feet per minute

per acre assumed by Mr. Dick for designing the waste weir was correct for scheme B according to Ziegler's formula.

The duration of any heavy rains is not likely to exceed two hours.

Greenwell and Curry give the length of the waste weir to be 2½ to 4 feet per 100 acres of watershed, or mean say 3·25 feet.

In scheme B, 90 feet is given for 3,000 acres = 3 feet per 100 acres.

(6.) Protecting Embankments.

The stone protection will not only save an embankment from the burrowing of rabbits, but also while new from the effects of the sun's rays, and when the bank is exposed to a long fetch from being pecked by spray. Cracks go deep, by the drying and shrinking of the puddle or clay, if the dam is unprotected by a good sod.

The President (Mr. Glover) said he looked upon the paper as a very useful one for reference. Engineers would find it very useful when called upon at any moment to give information or advice. The paper gave them an cutline of methods for prospecting and estimating for a water supply by gravitation. This part of an Engineer's work was of extreme importance, either in selecting a proper source or in arriving at preliminary reliable figures where but one source is practically possible.

It was manifest that in prospecting (or *reconnaissance*, if they might call it) the avoidance of expense was a great factor, more especially if they were engaged in competitive work, while quick decision in grasping the whole situation and possibilities was indispensable.

A preliminary report to a town authority may often make or mar a water supply scheme. Mistakes of over-estimating possibilities and expenses, or under-estimating, are about equally bad. The available acreage of gather-

ing ground, if a contoured map is available, aided by travelling the ground, can fortunately be ascertained with sufficient accuracy in a very short time. But, where there are no contours, by examining on a 6-inch Ordnance map, the position and the flow of streams, a line can be drawn showing approximately the dividing ridge.

Sometimes they were called upon to report on a water supply to a Board or some local authority at a very short notice—perhaps within a fortnight of the expiration of some legal time for application. Therefore, anything that would help them to make out their report was of the greatest importance.

The author gave a short, crisp figure, very useful and easily remembered, that 1,000 times the catchment in acres gave the available gallons per day it could supply.

(MR. DICK, interposing, said that was only when there was an available rainfall of 16 inches, fully utilised by providing adequate storage capacity.)

THE PRESIDENT—To members employed in gauging there was a figure that might be remembered also—viz., that gallons per minute × by 1½ gave about the number of thousands of gallons per day flowing. They would be obliged if the author could tell them what, in his opinion, was the practical minimum acreage of a catchment area for populations taken at 1,000 to 5,000; if he could tell them the average price per head for such populations, he would confer a benefit. The quantity of water per head of population was a very important point. Without stinting themselves some Irish towns of about 5,000 population consume less than 15 gallons per head, and this was important to remember lest they should condemn so small a supply.

The rate of flow through filters, which the author had referred to, was very important—the quicker, of course, the

cheaper; but too quick would wash away the sand. Besides a certain time for the passage of the water was necessary for the mere mechanical cleaning to be done, to say nothing of the biological processes now intruding themselves into what Engineers used to think was the sole domain of inorganic work.

A great deal, of course, depended upon the purity of the water to be filtered, the nature of the sand, and even the weather or rather the temperature. From 4 inches to 8 inches per hour seemed to be the extremes, and the author had chosen a good average at 12 feet per 24 hours.

As regards what Mr. Kernaghan had said, he thought it only confirmed what the author had told them with reference to rainfall and evaporation. They had all been taught that they could count about one-third of the rainfall as being available, also that evaporation from any water surface was about equal to the rainfall upon it.

Mr. Alfred Price said—With regard to the catchment area required for water supply his experience, and that of his late father, was that in Ireland, unless in exceptional cases, a minimum flow of twenty thousand gallons per day for every three hundred and sixty acres of catchment may be relied upon in calculating the capacity necessary for storage reservoir—that is about one-tenth of the average yield for an available rainfall of nine inches—according to Mr. Dick's neat rule $\frac{9}{16} \times 360 \times 1{,}000 = 205{,}250$ gallons available daily yield. In the absence of a long series of rainfall records and stream gaugings, taking out the catchment area for a projected water supply from the map, this rough estimate of minimum flow may be relied upon; but in a later stage, when working out the details of the scheme, accurate information should be obtained as to the conditions regulating the *available yield*, the *minimum flow* available for supply, and *maximum flood* to be discharged over waste weirs.

Mr. Dick said, in reply, the remarks of Mr. Kernaghan were mainly in support of the paper. He would, however, wish to point out, with regard to the exclusion of reservoir areas from the available catchment, that this should only be done when the reservoir consists of a previously existing lake, the area of which, after the construction of the works, remains when at its lowest summer level not appreciably different from its former area. In artificial reservoirs, on the other hand, it would be incorrect to deduct the top water area, because in summer that will be very considerably reduced. The well-known method of allowing so many lineal feet of waste weir per 100 acres cannot be recommended. With regard to the rainfall in dry years, the recent practice of the late Mr. Symons, who was a great authority on the subject, was to take the rainfall for 12 or more years and deduct one-fifth to give the average of three consecutive dry years, which is a different matter from the rainfall of one minimum year only, such as 1887. As to evaporation a great deal depended upon circumstances. The figures he had given throughout the paper were merely illustrative. As a matter of fact, the average evaporation and absorption on the land in the British Isles was from 14 to 15 inches per annum.

He did not think he could give any scale or table of catchment areas for small populations, for it depended upon the rainfall available and the supply per head which would be required. The capital cost of waterworks was often about £1 per head for small schemes, but it varied enormously. As to the chemistry and bacteriology of water supply, everyone knew that a thorough analysis of water to be used for drinking was essential.

He was glad to concur in the observations which had fallen from Mr. Price. Care was undoubtedly required to avoid over-estimating the minimum supply available at a given point during a prolonged drought.

[16th May, 1900.]

MR. EDWARD GLOVER, President, in the Chair.

The PRESIDENT presented to DR. W. E. ADENEY, D.Sc., F.I.C., the Chaloner-Smith premium of books, which had been awarded to him by the Council for his paper on "Sewage Sludges."

The following candidates were balloted for and duly elected:—

MESSRS. PETER CHALMERS COWAN, WILLIAM P. MOORE, FRED. J. DICK, and HENRY CHARLES BRETT, as Members, and Mr. JOHN QUIGLEY, as Associate Member.

HEATING BY STEAM, AT AND BELOW ATMOSPHERIC PRESSURE.

By W. R. MAGUIRE (Associate.)

HEATING by steam has been adopted much more extensively in America than in Europe, and consequently the special experience gained by American Heating Engineers is so much in advance of our practice that we can with advantage learn many lessons from them, and we are bound to admit that they are always willing to share their special knowledge with us. The Members of the American Society of Heating and Ventilating Engineers when in meeting assembled speak out with perfect candour of their failures as well as of their successes, and share the full benefit of their practical experience one with another in a manner worthy of our admiration and imitation. In this paper it is not intended to describe in detail the ordinary system in vogue for heating by steam, except so far as it may be necessary to indicate some of the difficulties and draw-backs which the vacuum system overcomes.

It may, perhaps, be well to refresh our memories with a

brief review of some characteristics of steam heating. We may remember that there are various units of measurement of heat, and that it is necessary when considering figures given in papers on the subject of steam or other heat to ascertain what system of measurement the writer is dealing with.

There is the calorie or unit of the metric system in France and elsewhere, which is the amount of heat required to raise 1 kilogramme of pure water through one degree Centigrade from (0°) zero Centigrade. And also the small calorie on C. G. S. system, in which the gramme takes the place of the kilogramme.

The thermal unit employed in calorimetry is the amount of heat required to raise 1 lb. of pure water through one degree Centigrade from zero Centigrade; while the British thermal unit, the B. T. U. with which heating Engineers are most concerned, is the amount of heat required to raise 1 lb. of pure water through one degree Fahrenheit, from 32° Fahrenheit, to 33° Fahrenheit, or from 50° Fahrenheit to 51° Fahrenheit, the very slight difference by the scale being negligible.

Other units are also used; but with different units of course all figures of measurement depending on them will be different. For instance, the latent heat of vaporisation taken up and concealed in the conversion of water at 212° Fahrenheit to steam at 212° (is 536 thermal units centigrade scale), or 966 British thermal units Fahrenheit scale. Heating Engineers in this country adopt the B. T. units in practice.

The expenditure of 1 B. T. U. is equivalent to the work of raising 772 lbs., 1 foot high, and vice-versa, Professor Joule's mechanical equivalent of heat. It will raise the temperature of 1 lb. of pure water, or 4 lbs. of dry air, 1° Fahrenheit. The sensible or apparent heat of steam at

atmospheric pressure shows 212° on the thermometer, but the steam also contains 966 British thermal units of latent heat, giving a total of 1,178 B. T. U., above zero per lb. of steam. In raising the temperature of 1 lb. of water from 32° to 21°, therefore 180 units are expended which with 966 units taken up as latent heat on turning to steam makes 1,146 units per lb. of steam which may be accepted as a standard for all pressures of steam in warming. The total of sensible and latent heat is nearly the same for all pressures for ordinary steam heating purposes,

These ordinary systems of steam heating are as you know arranged for low pressure, 1 lb. to 15 lbs.; moderate pressure, 15 lbs. to 40 lbs.; and high pressure steam, 40 lbs. to 100 lbs. per square inch. In all these systems the steam is turned into heating pipes and radiators which are already filled with air at atmospheric pressure, 14·7 or 15 lbs. per square inch.

It has been supposed that the greatest economy in heating can be attained by utilising the highest steam pressure on the ground that as pressure increases temperature increases—starting with 1 lb. pressure we get 216°.

5 lb. = 228°	20 lb. = 259°	50 lb. = 298°
10 lb. = 240°	40 lb. = 287°	105 lb. = 340°

therefore we expect a more rapid difference of heat per square foot of radiating surface with the higher temperature than with the lower temperature, and we think we ought to secure a greater efficiency and economy as a result. This paper will ask you to regard the very opposite theory as correct in arranging heating installations. In the first place intense heat is not desirable in any radiating surfaces for heating dwellings. The air in contact with highly heated surfaces is injured more or less, and it will be found that a large surface at the moderate temperature of 212° for warming air slowly will give far more pleasant

and healthful results than a smaller surface at 300° or 350°, over-heating the air rapidly.

With steam at 10 inches of vacuum *below* atmospheric pressure, as shown on vacuum gauge, the thermometer shows 192°, but including latent heat the value for steam heating purposes is 1,140 units per 1 lb. of steam.

At 5 inches below on vacuum gauge 202° total value for heating = 1,142 units per 1 lb. of steam.

At atmospheric pressure when no indication is shown on either vacuum or pressure gauge, the temperature shown is 212°, and total value including latent heat is taken as a standard for all pressures at 1,146 B. T. U. per lb., from 32°.

Steam at 5 lbs. above on pressure gauge, thermometer = 229°, and total = 1150 from 32°.

At 10 lbs. above on pressure gauge, thermometer = 240°, and total = 1154 from 32°.

At 100 lbs. above on pressure gauge, thermometer = 337° and total = 1184 from 32°.

So that between atmospheric pressure and 100 lbs. pressure the total increase is only 38 units per lb.

When the steam is kept under pressure as in ordinary steam plants, whether at 5 lbs., 10 lbs., or 100 lbs., this slight difference in heating power is not fully realised for heating purposes, it exerts force on the sides of the apparatus, and if applied to the piston of an engine would expend itself in work, but as it cannot escape, the increased units of heat remain in the steam as stored energy until it is expanded in some form.

When steam is condensed to water under its own pressure the total of apparent and latent heat cannot be counted on, as the latent heat due to the given pressure becomes less at every added lb. of pressure. Thus latent heat absorbs in units per lb. at 0 lb. = 966 units, at 7 lbs. =

950, 15 lbs. = 937, 20 lbs. = 931, 30 lbs. = 920, 60 lbs. = 897, 100 lbs. = 876, and it only yields in condensation the amount it absorbs. Therefore as the heat relied upon for supplying radiated and convected warmth to buildings is chiefly the latent heat given out in the condensation of the steam to water there is not such evident advantage as was supposed in increasing pressure in order to increase heating power when the cost of increased amount of fuel required is taken into account.

The average of the pressures employed by Engineers has been lowering year by year till now, with an average of pressure in heating plant of under 10 lbs., it is found that to secure the best results in efficiency and economy we may use steam at or under 212° Fahrenheit.

In heating installations having piping of great length with radiators in numerous positions filled with air at the ordinary atmospheric pressure of 14·7 it was found absolutely necessary to produce an initial pressure of steam considerably above that atmospheric pressure, in order to force the steam into the system against the pressure of the air in the apparatus, and against the obstruction arising from friction in the pipes, and from condensing steam. The only way adopted by Engineers to overcome these difficulties appears to have been to increase the steam pressure, and when the apparatus was strongly installed, and able to resist high pressure it was found easier to obtain good results under high than under low pressure. Greater care had to be observed in arranging a low pressure steam apparatus than a high pressure apparatus. It seemed that the steam at high pressure forced its way over and through obstacles that seriously impeded the effect of low pressure steam.

In the ordinary systems the circulation of steam is produced by maintaining a pressure on the supply mains, and

branches sufficient to propel the steam through the pipes, and radiators against the pressure of the air with which they are filled. Air valves which open when cold, and close when hot, automatically, are placed at the various points of the apparatus, where the Engineer supposes that the air is most likely to escape quickest. It is not always possible to provide for the exit of all this contained air because the hot steam moving under pressure follows the most direct course, and reaches the automatic valves before all the air has been driven out, closing the valves and bottling up a large amount of air in the radiators.

From 5 to 10 per cent. of air is contained in all water not boiled. It passes off with the steam into the heating apparatus when the water is boiled, and it collects in the radiators, and there continues to give trouble; even when the water returns to the boiler, and is boiled repeatedly air is still found in the system, and every time radiators are cooled air enters and takes the place of the steam, so that every time a radiator is heated air must be expelled before efficient heat is attained. Air has $1\frac{1}{2}$ times a greater density than steam, even up to 10 lbs. pressure, and, therefore tends to fall below steam when at rest. In steam heated radiators the air valve is usually fixed on the last column, about $\frac{1}{4}$ of the height from the top on the theory that all the air drops to the bottom of the radiator, and is driven up the last column, and out at the air valve, but in practice air is often found bound in the top of the radiator.

Air is one of the principal obstructions and difficulties to be dealt with in steam heating apparatus. It minimises the results obtainable from any given amount of fuel, in whatever proportion it is found absorbed in the water of the boiler, in the steam itself, or located within the heat radiating portions of the apparatus.

By observing the behaviour of water condensed from steam in glass pipes we are able to see that it does not as is generally supposed, fall into the invert of the pipe to flow along the bottom as a stream on its way back to the boiler, but that the drops cling by cohesion or capillarity to the interior surface of the pipe all round, so that in steam pipes whose area is contracted and barely sufficient for the required flow of the steam, the condensed water often causes obstruction, and other serious troubles, and is not all caught and removed by a drop pipe from the invert, but should have an enlargement all round the pipe, wherever a drop pipe is taken off. We are not able similarly to observe the action of air in experimental glass pipes or radiators, because both air and steam are invisible; we therefore know less about the distribution and action of the air in a steam apparatus than we know about the action of condensed water, and it is therefore more difficult to handle; but we cannot avoid the experience that both air and condensed water cause trouble. The air in a radiator after some considerable time becomes heated by the contact of the steam, so that even when we place several small air vents at different levels on a radiator we cannot judge accurately on opening them whether it is heated air or steam that is escaping. However, the fact remains evident which is sufficient for my present purpose that air in steam radiators or pipes reduces the heating power in proportion to the amount of air remaining in them. The air is supposed like the condensed water to adhere to the inner surfaces of radiators, and get into pockets at top or bottom of radiators in inexplicable ways, which, while puzzling heating Engineers, keeps the hot steam from direct contact with the rough iron inner radiating surfaces, and acting as a non-conductor of heat, prevents the radiating surfaces from attaining anything like the temperature due to the steam actually within the radiator.

With such a condition of things, a considerable amount of pressure power (or fuel) is required to maintain circulation and force up the temperature of heating surfaces to the desired degree.

The novel and simple idea occurred to Mr. Paul, an American heating Engineer, patentee of the heating principle bearing his name, that the best way to overcome the difficulties of forcing the steam into an air filled apparatus was first to remove the air which caused the difficulty.

He, therefore, proposed to extract or pump out the air causing a partial vacuum, throughout the whole heating system, to the extent represented by a 15 inch or 20 inch column of mercury. For this principle Mr. Paul took out what appears to be a very distinct and well secured valid patent. The Webster Patent covers the principle of extracting the water of condensation along with the air.

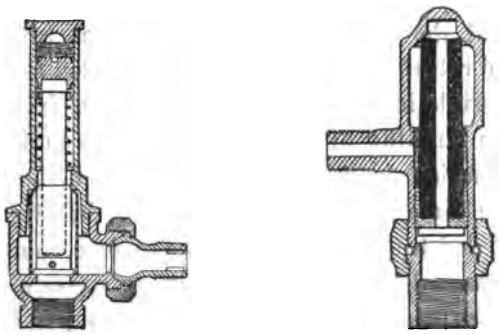
In the Paul vacuum system, whether on the one or two pipe method of heating, the several radiators are fitted with specially constructed simple air valves placed sufficiently high up on radiators to prevent flooding by condensed water. Opening for air and closing for steam contact, small exhaust pipes $\frac{1}{4}$ inch or $\frac{3}{8}$ inch diameter, attached to these valves are run alongside the steam supply pipes, and connected into vertical exhaust pipes which vertical pipes are in turn connected to a $\frac{3}{4}$ inch or 1 inch horizontal exhaust pipe in basement, which is led to the engine room, where is provided the apparatus for exhausting or sucking the air out of the pipes and radiators.

This apparatus or exhauster is supplied with either steam or water, at a pressure of about 40 lbs. per square inch. It is in fact a special form of ejector fitted with a controlling valve. When this valve is opened the steam or water rapidly exhausts or sucks the air from the pipes and

radiators, and in a few minutes time produces a partial vacuum throughout the installation, the extent of which is indicated on a vacuum gauge provided. When this gauge shows that a vacuum of 10 inches or 5 lbs. under atmospheric pressure has been produced, the installation is in the most perfect condition, freed from air and waiting for the reception of the steam for heating, which may then be turned in at any desired temperature with or without pressure.

In the Paul system all condensed water flows back to the boiler on the gravity system common to all ordinary one or two pipe steam heating plants, without the intervention of any mechanical pumping engine.

The Webster system of vacuum steam heating differs from the Paul system in some details, and is more advantageous in some circumstances. Instead of a steam ejector for exhausting the air a direct vacuum pump driven by live steam at 15 or 20 lbs. pressure is employed to pump out the air together with the condensation water. The radiators are always fitted with branch return pipes suffi-



ciently large to handle all the condensed water, these branches are connected into main returns leading to basement where all are united and connected to the vacuum pump. These branches are connected with each

radiator at the bottom, on the side furthest from the point where steam enters, and a specially constructed thermostatic valve is attached between the branch pipe and radiator.

These sections of the valve explain its construction which is simple. When cold air is in the radiator, and in contact with this valve it lies open. When hot steam reaches the valve it closes tight, and as soon as water condensed from the steam accumulates, the contact of the water partially opens the valve, allowing the condensed water to pass, closing tight when the steam again reaches it. The vacuum pump is depended on to remove the water of condensation, and also the air from the installation; in large installations duplicate pumps should be provided.

In an installation on the Webster system having 10,000 feet of radiation at work, in cold weather 3,000 pounds or 300 gallons of water will be condensed per hour, and the pumps must be sufficiently powerful to dispose of this amount with facility. The water and air are pumped into a steam heater, sealed from the atmosphere, and from this heater the air escapes outside the building while the temperature of the water is raised by contact with exhaust steam, and returned by automatic pump action to the boiler.

It is possible in a perfectly designed steam heating plant to heat the building by latent heat only, so that the water of condensation is started back to the boiler showing almost the same temperature as that of the steam in the radiators, and this gives the very acme of economy. This economy can only be secured when using steam at or under atmospheric pressure at or under 212° temperature.

It is generally supposed that the extra amount of fuel necessary to raise steam from atmospheric pressure, 212° to 5 lbs. pressure, 227° will yield its full excess of heat at the radiators.

If you have 212° at atmospheric pressure inside the radiator we find about 190° on the outside radiating surface If we have 227° at 5 lbs. over atmospheric pressure inside the radiator we find about 205° on the outside radiating surface, an increase of less than 5 per cent., while a considerable amount of fuel was consumed to attain that increase,

The heat is distributed from radiators less by radiation than by the action of the passing air in rubbing off the heat from the surfaces by convection, and the amount of heat thus developed depends on the velocity of the passing air, which velocity is only slightly increased when the radiator surface is 205°, as compared with 190°.

Very elaborate experiments have been carried out in America, which prove that with the vacuum system it is more economical to heat with steam at zero pressure, and that the less the difference between the temperature of the steam in the radiator, and the temperature of the air in the building taken at 5 feet level over floor, the greater is the economy of steam used.

The Paul system seems to be regarded as specially suited to high buildings, having a one pipe system, and where the condensed water flows rapidly by gravity back to boiler.

The Webster system finds special favour in large low buildings, having a two-pipe system, and wherever difficulty exists in dealing with the condensed water.

When saturated steam at atmospheric pressure (*i.e.*, steam at a temperature due to its pressure) is admitted into a heating apparatus which is maintained at a vacuum, it instantly expands, and thereby becomes superheated, possessing a higher temperature than is due to its pressure. Steam in this condition requires a medium through which to transmit its excess of heat, so it gives out this excess of heat freely through the radiating surfaces before it drops to its

normal condition as saturated steam; and the greater the vacuum we create the more benefit we gain from the superheating property of steam without additional cost, except that for the production of the vacuum, or about one shilling per day for a plant with 10,000 feet of radiation.

The difficulty in modulating temperature with ordinary steam heating plant is very great. Steam radiators must be turned full off or full on, hot water radiators can be modulated by their valves to any temperature, on the Webster vacuum system of steam heating this advantage is gained There is but one valve, and as it is closed the rate of condensation and the heat is controlled effectually in each room by the occupant.

The exhaust steam from engines such as are now almost universally used for electric light, elevators, pumping, and other machinery in hotels, public buildings, hospitals, factories, &c., has been allowed to go completely to waste to such an extent that in many English towns one can see as much steam blowing away to waste as would be amply sufficient to warm every building in the town. This waste has been justified by engineers on the ground that, in order to utilize it for extensive heating, pressure must be secured, and if pressure is secured, that means such an amount of back pressure on the engine pistons that no real saving of fuel would follow.

So far as the utilisation of exhaust steam for heating under pressure is concerned the engineers are right. Loss caused by any back pressure is very serious loss; but when the exhaust steam is turned into a heating installation, in which there is a vacuum owing to previous withdrawal of the air, back pressure on the engine no longer exists, but on the contrary the utilisation of the exhaust steam for heating actually helps the engine in its work.

In certain favourable combinations of circumstances the heating engineer may safely promise, by the careful exercise of his skill and ingenuity, to heat the building by utilising the waste from exhaust steam of engines free of all additional cost for fuel.

Exhaust steam escaping from the engine will not travel to distant points of a heating plant, unless it is supplied under pressure, which means steady back pressure on the engine piston during the whole period of its stroke; careful consideration of the effect of 10 lbs. back pressure on a piston working under, say, 80 lbs. pressure with a mean effective pressure of 45 lbs., will show that during a portion at least of the stroke, when the steam value is cut off wholly or in part, a steady 10 lb. back pressure would amount to a serious check, resulting in a very considerable demand on the fuel if the full horse power of the engine is to be maintained, resulting in a loss of about 20 per cent.

The vacuum system removes all back pressure from the piston completely, and helps rather than retards the work of the engine.

In these days of close competition it is of the greatest importance to manufacturers to utilise every waste product by modern processes. Chemical science has turned losses into profits with many different products by such utilisation. Why, then, should the heat of exhaust steam be thrown away "like rubbish to the void," as at present, when the vacuum system offers a means of inducing steam at the mildest and most beneficent temperature to flow rapidly and easily, without any apparent pressure on the gauge or back pressure on the engine, to permeate the most extensive installation with ease and speed, and to distribute its heat with healthful efficiency where it is most required.

The advantages fairly claimed for the vacuum syste are—

A rapid result of heating when steam is turned on;

A constant flow of steam to the radiators without pre sure;

A great economy of fuel owing to the use of steam low temperature;

A greater salubrity in the quality of the warmed ai

Automatic extraction of air and water from the app atus;

Absence of all water hammer noises;

Absence of leak or drip from valves;

Absence of odour, as no steam or air from the pl escapes into building;

All radiating surfaces are kept in effective radiat conditions;

All condensed water is returned at high temperat to boiler;

Exhaust or waste steam can be used without b pressure;

The temperature of each radiator may be modulate will by turning the valve;

No greater amount of radiating surface is require heat a building, because the whole surface is stantly and fully utilised owing to the comp and continuous withdrawal of air;

The condensed water may be returned to boiler a nearly at, the temperature of the steam, the h ing being effected by the latent heat of the st alone;

Radiators may be fixed below the line of drip or dr age if necessary, as the vacuum will lift the conde water about one foot high for every inch of vacuum m tained.

The system is also equally economical in paper, and textile mills, where the waste exhaust steam can take the place of the live steam now being used; and it is stated that not only is great economy secured, but that the quality of the paper, &c., is better and of more even texture, the speed of the rolls being much increased.

This paper may now conclude with a description of a Paul system of vacuum steam heating, given by Mr. M. O. Kasson, an American Engineer, who has had a wide experience:—

"Now, let us put it in operation. Steam is admitted to the exhausters, and soon we have formed a vacuum, the air having passed from all the main pipes and radiators through the air valve, and so on to the exhauster.

"This whole operation takes but little more time than its description, for these exhausters handle air rapidly, and presently we have the whole system under tension, and the pressure of the atmosphere stands ready to do the work of forcing the steam to the point of use.

"We will say, for example, that we have produced a vacuum of 10 inches on the pipes, which means that the absolute pressure within the system is 10 pounds per square inch, and if we then admit steam to fill the pipes at atmospheric pressure, or, in round figures, 15 pounds per square inch absolute pressure, the unbalanced pressure is 5 pounds per square inch in favour of the entering steam. So we then have the same condition of force that we had in the old system when we carried 5 pounds per square inch gauge pressure.

Before going any further, let us ascertain what it has cost us to produce this condition.

"Experiments made under actual working conditions show that the steam consumption of the exhausting apparatus is 50 pounds per hour, or 1,200 pounds per twenty-

four hours. Assuming the cost of evaporating 1,000 pounds of water to be tenpence, and a plant of 20,000 square feet of radiation will necessitate two sets of exhausting apparatus, it will cost two shillings to produce the condition just described and maintain them for twenty-four hours.

"The first question that a business man will ask is, 'What compensation do we get for this daily expenditure of two shillings?'" That can be answered in this way. Assuming that the radiation installed is about evenly divided between the two standard types of radiation, the Perfection loop and the Italian flue, the ratio of the cubical contents to the square feet of radiating surface in the Perfection loop is 1 to 31, and in the Italian flue it is 1 to 40, so that the average ratio of cubical contents to the radiating surface on the entire plant will be 1 to 35·5. On the sized plant we are discussing, at 20,000 square feet of total radiation, the cubical contents of the radiators will equal 563 feet, and to this may be added 437 cubic feet for the cubical contents of the necessary pipes and connections making the total cubical contents of the whole heating system equal 1,000 feet.

"According to the authorities, 1 lb. of steam at atmospheric pressure occupies 26·14 cubic feet of space, and 1 lb of steam at 5 lbs. gauge pressure occupies 19·91 cubic fee of space, so that in operating the plant at atmospheric pressure, we evaporate 38 pounds of water to fill th pipes and radiators with steam; while at 5 lbs. gaug pressure we must evaporate 50 lbs., or 12 lbs. more water, t accomplish the same result.

"As before stated, each square foot of radiation condense approximately three-tenths of a pound of steam per hou under atmospheric pressure, equalling 144,000 pounds o condensation in twenty-four hours when worked to it limit. While under 5 lbs. gauge pressure the condensatio

will amount to 187,488 pounds figured by the ratio of displacement of steam at the different pressures. In round figures we have been obliged to evaporate 43,500 pounds of water to do the work of forcing the steam to circulate, and have used to evaporate this extra amount of water 23 per cent. of the total coal consumed, so that for the expenditure of two shillings per day we have been enabled to make a saving of something over one-fifth of the coal bill.

"These deductions have not taken into consideration the slight difference in the total heat of steam at the pressures mentioned, but many actual tests under ordinary conditions show a saving of 20 per cent, at the coal pile.

"Incidentally we have accomplished another result by thus removing the air from the radiators, which, while it does not effect the economy, adds greatly to the comfort and health of the inmates of the building. When the weather is cold enough to necessitate artificial heat, the windows and doors are kept closed to confine it, and ventilation is reduced to a minimum. If the air within the radiator is then forced out into the room we all know the result from experience. It is not the odour of 'new mown hay,' and it clings to the contents of the room as 'the odour of roses clings to a broken vase,' only more so, and a whole summer of ventilation usually fails to dislodge its obnoxious presence.

"This system is operated mainly by the condensation of the steam which has given up its heat to the atmosphere, and a brief description of the methods employed to accomplish this may interest you. Each radiator is provided with an automatic air valve, the inlet of which is screwed into the radiator high enough up to prevent the water from flooding it, and the outlet is connected to the exhausting apparatus. When the radiator is cold this valve remains open, and the air in the radiator is under tension due to the pull of the

exhausting apparatus. When steam is admitted it enters with great rapidity, and, on reaching the valve, the valve closes by expansion. The valve then remains closed as long as the radiator is filled with steam. Every particle of steam that condenses makes room for more steam to enter to fill the space.

"An illustration can be obtained by placing a stop valve in the air-pipe outside of the automatic air valve. When the radiator has been filled with steam, close the communication with the exhauster, and it will continue to work for hours by the power of condensation alone.

"There is just one more point that should be explained before we close. I have spoken of the water of condensation flowing back by the force of gravity, and so it does in most cases, but we all know that water don't run up-hill, and circumstances sometimes compel the placing of the receiving tank on a higher level than the return pipes; or perhaps where the steam and return pipes are hung on the ceiling, it is desirable to place a radiator on the floor. Then the water of condensation must be lifted, and here again this System utilises natural forces to accomplish the result and it is done in two ways, differing slightly in detail.

The apparatus is a most simple and ingenious one. It consists of an inlet check valve connected to a vertical pipe usually $\frac{3}{4}$ inch by 5 feet long, terminating in an elbow which is connected by a short horizontal nipple to another vertical pipe 6 feet long, about one foot from its upper end and on the lower end of this another pipe is provided with an outlet check valve. The vacuum is connected to the top of this device by a patent capillary cock, which is an ordinary stop cock with a small channel cut around the plug so that when the cock is turned crossways there is still communication through this channel.

"In operation, when the air is exhausted from the pipe

water is forced in to fill the space; but when it reaches and floods the channel of the capillary cock, communication with the apparatus, is, for a brief period of time, closed, and the water falls by force of gravity down the discharge legs. When the water in the capillary cock has gone through, the operation is repeated, and the inflow of water continues as long as the supply and vacuum is maintained.

"I have seen one of such devices of the dimensions described handle all the entrained water from a tank, which received the exhaust steam from engines and pumps aggregating 150 horsepower, and as there are no moving parts it requires no attention."

The writer now concludes this paper, in which he endeavoured to bring a novel and interesting American method of heating before this Institute plainly and in simple language. The writer has had on opportunity of inspecting the system in action in London, where, in a large hotel, he was assured that a saving of 10 tons of coal per week had been effected by its adoption, and other advantages had also been secured in the prevention of water hammer, and in the speed of heating up distant radiators when required. At the same time the writer must record that he does not claim to have had a sufficient test of the system to enable him to press for its universal adoption; he does not consider it necessary or even suitable for every steam installation, but he thinks that the wide adoption of the vacuum steam heating system, using exhaust or live steam at or under atmospheric pressure, especially in the enormous buildings to be found in America, is *primâ facie* evidence that the subjecet is not unworthy of the consideration of the Institution of Civil Engineers of Ireland.

Mr. P. C. Cowan stated that he had much pleasure in testifying to the interest and value of Mr. Maguire's

paper which he especially appreciated as in recent practic he had been called upon to deal with difficult question regarding the heating and ventilating of large building:

Mr. G. M. Harris said he would like to ask the autho what increased radiating surface would be necessary com paring the vacuum system with the ordinary one at, sa five lbs. pressure.

It appeared to him, that if you decrease the temperatur at which you work you must increase the radiating surfac to get the same results and he would be glad to know ho this worked out in practice.

He would also like to know how the joints are kep tight—everyone who is familiar with condensing engine has experienced some little difficulty in keeping th vacuum up, which means keeping the joints perfectl tight, and this when dealing with perhaps less than 20 f of pipe. It would, therefore, easily be conceived how thi difficulty must magnify when it comes to some hundreds o joints distributed throughout a large building often i inaccessible places. He would like to know what kind c joint was used, and if provision is made for expansion, &c

Of course on a pressure system it was easy enough t detect a leakage by the appearance of steam or wate escaping, but with a vacuum it was not so easy, you coul see nothing.

He did not see how they could keep up a vacuum at th cost of 2s. per day, as set down in the paper. He believe they would require a very large pump to remove the ai and water from the system, and deal with leakages at th joints, and the cost of keeping up the vacuum would b the cost of running and keeping in repair this pum whatever that cost might be, but even under most favou able conditions he believed it would be much more than 2 per day.

In conclusion, he would wish to say that to him the paper was extremely valuable and interesting. The idea of using up the latent heat for heating purposes he considered a beautiful one, and provided there were no serious difficulties in practice such as he had indicated he would consider it a sinful waste to continue using a pressure system, and blow live steam to the atmosphere.

Mr. Prosser A. H. Shaw said.—It appears curious to note that although engineers have previously looked on a steam heating apparatus, very properly, as a condenser, they have not before come to the correct conclusion of working the condensing plant by the air pump, hence the vacuum system which has now been introduced.

He said he was probably the first person to introduce what is now known as the Webster vacuum system of low pressure steam heating into this country, having used it for the heating of a large printing house at St. James's Gate Brewery, two rooms containing about 60,000 cubic feet each having to be regularly heated during the cold weather, and from an early hour in the morning. The steam which is required for this system being only atmospheric pressure was taken from an exhaust steam main, and the small pump required only 10 lbs. of steam; this installation has proved a great success.

The first attempt at the vacuum system of circulating low pressure steam was made nearly 10 years ago, but was not a success on account of the difficulty of short circuiting of the steam.

The Warren Webster system, which has now been found to be the most perfect, secures a complete and rapid circulation of steam through a large system of radiators in such a manner that the most distant radiators from the steam supply are as easily heated as those close by, this being effected by the Thermostatic valve attached to the

radiators, which when adjusted allows the condensed stea from the radiators to be drawn off by the vacuum pull i the return pipe, but closes on the pressure of the followin steam, and does not again open until the condensed stea at a lower temperature affects it again. This princip thus gives an immediate heating to the whole system whic is an enormous advantage, and also the controlling of tl heat, which has been one of the great objections to stea heating heretofore, is entirely successful in the Webst system. The radiators can be kept at any temperatu from 90° to 212°, and the following conclusions are no acquired facts:—

1. That it is more efficient and economical than the h water system, and more especially when exhaust steam ca be used.

2. The circulation is perfect, rapid and controllable.

3. It is noiseless in working and requires very litt attention.

Mr. Shaw used the American radiators which ha many points to recommend them, they are very tidy appearance, easily accessible for cleaning and easily ma good if they become defective.

He was sure the Members of the Institution were mu obliged to Mr. Maguire for his paper, which would form useful chapter in the Proceedings of the Institution, a it was one which had brought forth a most healthy di cussion.

The President.—I think Mr. Maguire is correct saying that the subject of his paper is worthy of our co sideration, but except upon lines more or less theoretic I am unable to speak, having no experience of heating described in the paper. Mr. Maguire's statement abo coal saving, quick heating of distant points, &c., in a ca recently inspected by him looks well. In a pamphlet i

ceived from Messrs, Ashwell & Nesbit, Licensees for the United Kingdom of the Paul System, there are many testimonials printed showing efficiency of the system for drying work as well as heating. The Atmospheric Steam Heating Company, Chancery-lane, London, works the Webster system. For our purpose, we may, I think look at the two systems as alike, the underlying principle is the same, although some details are different, notably those referring to return of condensed water. Whether one system is as good as the other need not concern us, I think, this evening. I remember seeing heating done by the visible exhaust from an engine being made to travel about 150 feet of pipe with a free end. Piping was laid with a small fall from the engine, and the condensed water gave no trouble. The place was a workshop, and the heating was considered a success. No doubt the friction from the long pipe caused back pressure. But, of course, a visible exhaust is not steam any more than clouds are. Steam which escapes into the atmosphere and becomes fog by condensation can be preserved as steam if we have a reservoir or system with a pressure within it less than the atmosphere. Is it cheaper to force against a "tail race" pressure, or remove the pressure partially or wholly? This is entirely a question of engine work, and the answer I think must be that the manufacture of a vacuum is more expensive than putting an extra force to overcome back pressure. Therefore, on this particular point one should conclude that heating at and below atmospheric pressure must be more expensive than at pressures over the atmosphere. But, apparently, the question of mere engine work touches only the fringe of the subject. Air cushions, or films, are proverbially difficult to deal with, and the higher the pressure the worse, because the specific heat is greater. This alone should be in favour of the system of heating in

Mr. Maguire's paper. But the chief favourable point to considered would appear to arise from consideratio about latent heat. By reduction of pressure heat is lib rated which can travel around. The most of this free he at higher pressures was consumed and held fast by t steam itself, for its own maintenance. If steam, ther fore, is looked upon as a means for conveying and disti buting heat through buildings it should seem that t lower the pressure the cheaper—consistent with the tei perature required. I think we should feel indebted to M Maguire for his paper. What Mr. Shaw says is instru tive, as he has found the system satisfactory, and I ho that at some future meeting any member having expei ence will give us the facts and results as observed by him

Mr. Maguire, in reply, said:—With reference to M Harris' remarks about the question of keeping the joir tight, Mr. Shaw could have told them that he had not ve much trouble with leaky joints. Of course, if a joint d leak, it at once showed on the vacuum gauge. The gau begins to go down immediately if there was a leakage.

Then if they wanted to find the leakage, they had simp to turn in the steam or water, and it was soon foun But leakages rarely occur when the work is well carri out in the first instance.

With reference to the cost of 2s. per day for the use steam to exhaust the air, he might explain that when tl steam had made the vacuum they could shut off the val for hours and hours, and the vacuum would remain, an no further steam would be required. A very sma amount of steam was required to keep up the vacuum, an Mr. Shaw was the first to introduce this system into tl country, and he was very pleased to hear him approve of i But there was one point which Mr. Shaw omitted to te them, and that was, that he got his steam for nothing.

One department of the brewery had a quantity of exhaust steam which they did not want; and they gave it to the other department provided that they took it at ordinary atmospheric pressure, so as to avoid any back pressure, Mr. Shaw was using this exhaust steam for his vacuum system so that practically he had his heating for nothing.

Any engineer could use either the Paul or Webster systems of heating. There was no sole agency firm. They were "Patent systems," but there was no monopoly in erecting them, the apparatus is open to all engineers. He had an account of a place in America where exhaust steam had been allowed to flow waste to the air, absolutely waste. An installation of the vacuum system was erected, whereby they were able to heat an immense factory by using this steam which before had been allowed to go waste. It flowed evenly through the whole extent of miles and miles of pipe, and heated them better than before, when formerly live steam was used, besides saving a large amount of fuel.

He was much gratified by the kind manner in which his paper has been received.

[6th June, 1900.]

MR. EDWARD GLOVER, President, in the Chair.

The evening was occupied by the discussion on M Dick's paper, "Some Notes on Waterworks," read meeting on 2nd May. (See pp. 31 to 38); and on M Maguire's paper, "Heating by Steam and below atm pheric Pressure" read at meeting on 16th May. (See 57 to 63.)

[7th November, 1900.]

Steam Road-Rolling.

By Michl. J. Buckley, Member.

Introductory.

The latter half, and more particularly the last quarter, of the nineteenth century has been productive of much scientific research, not only within the walls of our college laboratories, but also outside throughout the wide expanse of Nature's grand laboratory, the Universe, where man has made many discoveries and learned many lessons, not the least important of which are the unfathomable depth of his ignorance, and the existence of the still immeasurable store of knowledge which remains to afford him that most delightful of all occupations, the struggle for the acquisition of a more thorough comprehension of natural phenomena for the purpose of "directing the great sources of power in Nature for the use and convenience" of his fellow-man. On further study of the definition of the knowledge which constitutes the profession of a Civil Engineer, as set forth in the Charter (just quoted) of our Sister Institution of London, we find the first item mentioned therein to be the construction of roads, from which fact one may reasonably infer that the leading members of our profession three-quarters of a century ago attached very considerable importance to this branch of work. It could hardly be otherwise in times anterior to railway construction. However, notwithstanding the number of means which are available for conveyance of matter and thought at the present day, and which were unknown at the date of the

formation of that definition, the construction—which m: here be taken to include the maintenance—of our roa demands considerably more attention now than then. T days of the lumbering coach are past, those of the pne matic-tyred wire-spoked vehicle are forcibly present.

The refinements of modern civilisation every day te to increase the amount of exacting attention necessary the part of the responsible authorities to all things touchi the comfort of the public, and when once the public h tasted the pleasure of any of those refinements it chaf under the newly-discovered hardships of the old order things and calls for their removal. The user of t suburban highway of fifty years ago, unacquainted wi the effects of road-rolling and its consequent comforts, w satisfied with his roads provided they had a reasonab amount of attention during the winter months, demandi little more than that the pools of water should be swept o and the sites of those pools filled with stones broken to approximately uniform size of a couple of inches. T user of the suburban highway, and indeed of many a rur highway of to-day, must not be subjected to the discomfo of having the wheel of his vehicle jolted by a loose sto on the road or bumped into a rut and out again, nor w he suffer without murmur to have his horse and tr bespattered with mud in wet weather, while residents suburban districts will not at the present day submit wit out protest to have their clothes and furniture spoiled the dust which is generated so plentifully on badly ke roads in dry weather. A good smooth surface is co ducive to comfort in driving, and less fruitful of the mu hated dust storm, and since such a surface is most readi obtained by steam rolling, this process is beginning to universally recognised as a necessity. The efficacy of stea rolling is a comparatively recent discovery. It is t

result of the application of a source "of power in Nature for the use and convenience of man."

Consideration of Expense.

The relative cost of maintaining a road (*a*) by the aid of a steam roller, and (*b*) without it, in any locality decides whether steam rolling is to be introduced at once or delayed until the voice of public opinion cries out for it, but sooner or later all roads with any considerable amount of traffic will have to be rolled. The expense which has to be incurred in supplying materials to form a proper section by the aid of a steam roller for an ordinary macadam road which has never been rolled before has deterred many road authorities from more widely availing of the advantage of steam rolling. In nearly every case the old roads have a concave transverse section which is, as a rule, much more pronounced when the road has a longitudinal inclination; and in consequence of this the centre or crown of the road has to be raised a considerable height, often as much as from twelve to fifteen inches, in order to ensure that all the water which falls on the road may reach the channel courses. This entails a very great outlay in the first instance, and very few authorities are willing, even when they can afford it, to spend the amount required to thus properly form any considerable mileage of their roads.

Bye-Laws Confirmed by the Local Government Board.

In the formation of new streets, according to the requirements of bye-laws made with the sanction of the Local Government Board, it is necessary to construct a foundation of large pitching stones, forming a layer six inches thick over the entire area of the carriage way; over this must be spread a second layer, six inches thick, of good macadam. When the work is properly and carefully exe-

cuted with such materials, on ordinarily good ground, th result is an excellent macadam road, and if, in addition, a steam-roller is used, an ideal surface is obtained, and on which is capable of withstanding the effects of ordinar traffic of rural and suburban districts for a very grea number of years, provided a small annual expenditure i made in rolling in patches wherever it is observed tha small depressions are making their appearance.

Pitching Impracticable in old Roads.

But in dealing with the existing thoroughfares, the cos of laying down a rubble-pitched bottom renders such a cours impracticable, and the best that can be done usually is t put down five or six inches of good strong limeston macadam, and cover that with about three inches of superior stone, such as good granite or syenite.

Scarifying.

Some difference of opinion exists with regard to th necessity or advisability of scarifying. The author' experience has led him to believe that under certain circum stances it is indispensable, while under others it would b useless and possibly detrimental. For example, in the cas of a road which has been repaired for a number of year with greenstone, and which, in consequence, has a super ficial layer of good metal of fairly uniform thickness, a excellent surface may be obtained without incurring th cost of any new material by scarifying a few inches dee over the entire surface, moving, if necessary, from the side towards the centre a little of the loose material thu obtained, and then rolling. Or if, in the case jus mentioned, the surface requires to be raised, say, three o four inches, it will be most advisable, especially in very dr weather, to scarify in order to cause the new material t

bond with the old. On the other hand, in dealing with a very bad road on a soft subsoil, it is more than probable that the transverse surface section will be concave instead of convex, and that to set this condition of things right a very considerable thickness of material, perhaps even twelve inches in the centre, will be required. Not only would it be unnecessary to scarify such a road, but it would be a mistake to further weaken the old surface by so doing. One must have regard to all the circumstances when about to decide whether a road is to be scarified or not. A road that would require to be scarified in very dry weather might be very much better without it in wet weather; a great deal depends in such a case on the depth of material about to be laid down.

Opening Trenches with Scarifier.

A scarifier can be most usefully and advantageously employed in districts where occasion arises to open trenches in macadam roads for laying water-mains, gas-mains, constructing sewers, or any similar purpose which requires a long length of the surface of the carriage way to be broken in a direction parallel to the centre line of the road. The author has effected a very considerable saving in both time and money by the use of a scarifier in breaking the hard crust of a road where a water-main was about to be laid down. It was calculated that the saving in time was about 75 per cent., and in money about 66 per cent., for the work of loosening the top five or six inches of the trench.

Cost of Scarifying.

The cost of scarifying per square yard varies from a farthing to three farthings, according to the depth of material loosened and the resistance it offers. If occasion should demand it would be quite possible to loosen as

many as three thousand square yards of the surface of ord nary macadam roads to a depth of four inches in a day ten hours.

Diversion of Traffic.

The first point that has to be considered when a road is be steam-rolled is, whether the traffic over it will pern of being temporarily diverted through some neighbouri thoroughfare. If it will, then much more satisfaction c be got by doing so than if one half of the road has to left open. For, in the first place, a better section can given when the whole width of the road is rolled at on than when it is done in alternate strips along each side the centre line; in the latter case the work is only patch at best, and extra time is necessarily taken up in finishi the crown. And another consideration of great importan is that when the traffic cannot be diverted a great deal time is lost in stopping the engine to allow timid horses pass, and the flagman is engaged in the unproductive occ pation of holding a stick with a red rag fastened to it wh he might be usefully engaged in sweeping or spreading.

Method of Procedure.

The stones are first spread over the surface and rolled f some time while still dry and free from binding material any kind. This operation continues until the surface h been properly shaped with a moderately raised crown and gentle, curved incline to each channel course. When t work is superintended by an experienced man, very lit alteration in the first disposition of the stones when spre after having been emptied from the carts, is necessary. few shovelfuls of stones scattered here or there to fill up slight depression is usually all that is required. Some f road sweepings, as free as possible from refuse, such straws, horse-dung, &c., should then be scattered over t surface in such a quantity as to just fill up the small spa

which still remain between the stones of the topmost layer. In this connection it may be well to state that it has been found to be worth while to collect and store sweepings obtained from a road after a heavy downfall of rain, as the impurities above named will then have been carried off and an excellent binding material left behind. A watering cart next passes over the part so covered with road sweepings and sprinkles a liberal supply of water on it. This enables the sweepers with the aid of strong road brushes to convert the sweepings into a mud grout, which passes down between the stones and serves as a cheap binding material to convert the surface into one continuous layer of macadam. It improves work which has been done a few days to go back over it with the watering-cart and thoroughly wet the surface, and then roll the entire width of the road, after which the sweepers follow and remove all the mud which the rolling brings to the surface, getting thereby to a great extent the advantage to be derived from closing the road to traffic while at work, the principal object being, however, to remove superfluous mud from the upper layer of material and convert it as far as possible into a compact mass of stones. In practice the author has found it a good plan to spend the short working day on Saturday in carrying out this supplementary treatment on the surface formed during the previous five days of the week. In the course of a few fine days the material thus treated changes into a solid mosaic-like crust.

Advantage of Working in Dry Weather.

While it is a fact, as advocates of steam-rolling as opposed to the older method claim, that one advantage of the former method is that it can be carried on successfully at any time of the year, it must be said that a more satisfactory result is obtained from work done during dry

weather; for if three or four fine days occur immediately after the final rolling is accomplished, the grouting dries and the surface hardens, and is better able to withstand the effect of traffic.

Cost of Steam Rolling.

The question of cost is an all-important one. It varies very much according to circumstances, and it will be necessary to consider apart from one another

(*a*) The working expenses and

(*b*) The cost of material.

The former is relatively small, and, for practical purposes, may be regarded as a fixed quantity, while the latter, being proportionately very great, affects the variation of the aggregate cost to a great degree. In dealing with suburban roads which have never been rolled before, and which, as a rule, require a heavy coating of material, it is under ordinary circumstances a good day's work to spread and properly roll in fifty cubic yards of stone, which if put on in a layer six inches in depth would extend over three hundred square yards. It is possible to lay down a larger quantity, but it would be unwise to insist on having this done regularly every day, as the quality of the work would be most likely to suffer. The area which can be rolled in a given time varies approximately in inverse ratio to the depth of the material laid down; thus, if, instead of the depth just mentioned, three inches of metal is sufficient the area that can be efficiently rolled in a day will be about six hundred square yards. The reason for this is that, on account of the smaller amount of rolling required by the thinner layer of stones, the time spent in moving the roller over the larger area is approximately the same. In rural districts the area of road which can be rolled per day is much greater than in urban districts, and for several reasons, the two most important of which are that the interrup-

tions caused by horses becoming frightened are very much less, and that little or no precaution has to be taken to guard against damaging manhole covers, ventilators, gullies and surface boxes of various kinds, the absence of which obviates the necessity of spending time and labour altering their levels to suit that of the newly-formed surface. On an average seventy-five cubic yards of metal per day may be laid down and rolled in rural districts, while, as already stated, fifty is a good average for urban districts.

(*a*) Working Expenses.

The working expenses per day of the rolling are made up of the following items:—

	s.	d.		
Driver's wages	5	0		
Flagman's „	3	0		
Coal and coke	3	0		
Water for engine	0	2		
Oil, tallow and packing	1	6		
			12	8
Interest on, say, £500, at 3 per cent.	1	0		
Repayment of principal	3	4		
			4	4
Wages of two spreaders and two sweepers	12	0		
Watering cart, horse and driver ...	7	6		
Water used in sprinkling materials	1	0		
			20	6
			37	6

It follows from those figures that the cost per square yard ranges from about ½d. to 1d. in rural districts, and from about ¾d. to 1½d. in urban districts.

(*b*) Cost of Material.

As already mentioned, the cost of the material necessary

to properly shape roads which have never been steam rolled is usually very great, and this is in reality the great obstacle to the more general adoption of maintenance of highways by the aid of steam rolling. The cost of material ranges from about four shillings per cubic yard for limestone to eight shillings for good igneous rock, hence we find that the cost per square yard of the material for a three-inch layer varies from fourpence to eightpence, and if a coat of material six inches thick is necessary, which is not infrequent—the author having had in some cases to put down as much as fourteen inches—the cost per square yard of the material alone varies from 8d. to 1s. 4d., while the cost of rolling it varies from ½d. to 1½d. When the initial expenses of properly raising and shaping all the roads of a district have been met the subsequent cost of the up-keep of those roads in a thoroughly satisfactory condition ought not to be a heavy burden on the ratepayer.

Advantages of Using Best Stone.

Experience has shown that a road formed of good igneous rock wears better and requires much less attention in order to keep it free from mud and dust than one formed of limestone; moreover, the mud formed from limestone, being of a pasty non-porous nature, retards evaporation and obstructs the flow of surface water to the channel-courses, more than that formed on roads maintained with granite or any of the syenitic or dioritic series of rocks, and it has the further disadvantage, and one which will be admitted to be of some importance nowadays, of causing much annoyance and discomfiture to cyclists in damp weather by its greasy consistency, which is so fruitful of danger through skidding. For those various reasons, wherever it is possible, a surface coating at least three inches thick of the better material should be laid down.

Contour.

With reference to the shape of the transverse section of roads, care should be taken that the crown should not be raised above the sides more than is barely sufficient to allow the surface water to flow gently to the channels, as traffic has a tendency to avoid the sides of a road when they slope inordinately in a transverse direction, with the result that the middle of such a road is subjected to an undue amount of use compared with the sides. When the sides have a moderate gradient the area available for the convenient passage of traffic is greater than when the gradient is excessive, the intensity of the traffic is consequently less along the crown, and the life of that part of the road is thereby prolonged. The amount of fall from the centre to the sides also vitally affects the convenience of the cyclist, for with a single track vehicle like the bicycle it is extremely difficult to prevent skidding when travelling along a slope if the gradient is excessive. A simple rule, and one which will be found to work satisfactorily on most roads of average width, is to keep the crown and the upper surface of the kerbing on the same level, assuming the height of the latter to be in or about five inches. The transverse gradients resulting from the adoption of this rule will be found to work out at about one in forty.

Size of Material.

There is some difference of opinion as to what size the stones should be in the surface coating in order to give the best results. It is urged by some, prompted probably by a desire to effect economy, that the stones may be considerably larger when they are to be laid down with the help of a steam roller, while others urge that there is an advantage in having them small, giving as their reason that if a stone should get knocked out of its place, the hole left will be

small and will soon get filled with mud or dust. A middle course in this as in most things will be found to be the best. If the stones are broken to pass every way through a two inch ring, and so as to be more or less cubical in shape, very good work will be obtained. The size of the stones depends to some extent on the quality of the material used; for instance, it would not do to break an inferior limestone as small as greenstone may be broken. The stones underlying the topmost layer of three inches may be much larger.

Subsequent Care.

It must not be thought that when once a road has been steam rolled it may be left without further attention for any considerable time. To get full value from the necessarily heavy initial expenditure incurred regular and systematic cleansing should be adopted, and in dry weather the surface should be kept damp to prevent "ravelling." Moreover, heavy traffic soon tells on a newly rolled road, and depressions will in the course of time inevitably make their appearance along the crown. The practice of simply sweeping the road and leaving depressions otherwise unattended to, adopted by some authorities, is to be deprecated, as the result is that they gradually become enlarged and eventually extend over almost the entire area of the carriage way. They should be seen to at once, if possible, and after having been scarified fresh material should be rolled into them.

Advantages and Disadvantages of Steam Rolling.

The following very complete enumeration of the advantages and disadvantages of steam road-rolling is taken from Boulnois' "Municipal and Sanitary Engineer's Handbook." The advantages are:—

(1.) The saving of wear and tear to vehicles and horses.

(2.) Economy; as it is said that a saving of from 30 to 50 per cent. is effected by reason of the roads being better made; thus obviating the necessity for such frequent sweeping and scraping.

(3.) The roads can be made or repaired at any season of the year.

(4.) The avoidance of cruelty to horses, cattle and sheep, as in the case of newly metalled unrolled roads.

(5.) A saving of road metal:—

(*a*) Because it need not be broken so small.

(*b*) Because there are no loose stones to be kicked about and lost.

(*c*) Because there is no abrasion of the stones, only one surface of the stone being exposed.

(*d*) Because no ruts can be formed in which water can lie to rot the stone.

(*e*) Because a thinner coating of metal can be employed.

(6.) The roller can be advantageously used for other purposes.

(7.) Rolled streets have a better appearance, they are easier of traffic as having more evenness of surface and superior hardness; and it is contended that if steam rollers were more general there would not be such an outcry for other descriptions of pavement for roadways.

(8.) The steam roller soon finds out the good from the bad metal for roads; it is also contended that it also does this with respect to the gas and water mains; the latter, however, may be looked upon as a rather doubtful advantage.

(9.) The avoidance of the necessity of the continued employment of men raking the metal into the ruts.

The disadvantages are:—

(1.) The first cost.

(2.) The risk of damage to gas and water mains a services; or even of cellars under the streets some of the older towns.

(3.) The interference to traffic whilst the roller is work.

(4.) The noise and smoke.

(5.) The risk of frightening horses.

(6.) If too heavy a roller is used the foundation the roadway may be injured, or the metal may crushed instead of bedded.

(7.) The necessity of using so much binding mate and water.

Legal Aspects.

Some reference here to the law as it affects the adoption steam road-rolling is justified by a statement made by L Chief Justice O'Brien in a traction engine case which ca before him last year. His Lordship said "it was of c siderable importance that both the owners of these engi and the public generally should be acquainted with law upon the subject, and have a full knowledge of th rights and liabilities. This was the more essential, beca there seemed to be a widely prevalent idea, but one wh was wholly erroneous, that if a traction engine were c structed pursuant to the requirements of the statute, used according to statutory provisions, the owner was p tected, and incurred no liability for damage he did un such circumstances. It was thought that compliance w the statute, and the absence of negligence, formed a co plete protection for the owners of traction engines. T was wholly wrong; even if the owner of such an eng complied to the letter with every statutory requirement

was still liable to the public for any damages he might do, or injury he might cause by his traction engine, or any damage done by it which would not be done by ordinary traffic."

Injury to person or property may be caused in many ways; but a few typical cases will probably cover all except those which may arise under very unusual circumstances.

Powell *v.* Fall.

In "Powell and another *v.* Fall," tried in the Court of Appeal in March, 1880.

"The defendant was possessed of a traction engine which was propelled by steam power. Whilst it was being driven by the defendant's servants along a highway, some sparks escaping from it set fire to a stack of hay of the plaintiffs' standing on a neighbouring farm. The engine was constructed in conformity with the Locomotive Acts, 1861, 1865; at the time of the accident it was being driven at a proper pace, and the defendant's servants were guilty of no negligence in the management of it.

"Held, that the defendant was liable to compensate the plaintiffs for the injury done to the stack, upon the ground that the engine being a dangerous machine an action was maintainable at common law, and the Locomotive Acts did not restrict the liability of the defendant."

The principle on which the decision was based was: "That when a man brings or uses a thing of a dangerous character on his own land, he must keep it in at his own peril, and is liable to the consequences if it escapes and does injury to his neighbour."

Galer *v.* Rawson.

In "Galer *v.* Rawson and another," tried in the Court of Appeal in November, 1899, an action to recover damages for personal injuries.

"The plaintiff was driving along a high road ı Leicester in his dog cart, when he met a traction en; belonging to the defendants coming towards him. traction engine was stopped, and the plaintiff's groom down and led the horse by the engine. The horse bec: restive and bolted, dragging the groom along with it, and dog cart was upset, the plaintiff being injured. The (was tried before Mr. Justice Stephen and a jury, when jury found:—

"(1.) That the accident was not caused by the plaint negligence, or any other cause independent of engine.

"(2.) That the accident was not caused by the eng starting when the plaintiff's dog cart was passi

"(3.) That there was no transgression of any of statutory requirements on the part of those charge of the engine, and

"(4.) That the accident was caused by the plainti horse taking fright at the engine when lawfully the road and properly managed."

Upon these findings the learned judge gave judgment the defendants.

The plaintiff appealed.

The Court dismissed the appeal.

The Master of the Rolls stated in his judgment "tl there had been a miscarriage of justice, but that they co now grant no relief; he himself was of opinion that if engine of this sort fulfilled all the requirements of t statute, and yet was calculated to frighten horses of or nary nerve and courage on a highway, the engine was nuisance, and there was nothing in the statute to absol the owner from liability to pay damages to those wh person or property was injured in consequence thereof." is important to note that Lord Justice Lindley observed th

"they could not go to the length of saying that all traction engines were a nuisance."

ARMAGH GUARDIANS *v.* BELL.

In Armagh Poor Law Guardians *v.* Bell, tried in the Queen's Bench Division in November, 1899.

"This was a case stated for the Queen's Bench Division by Chief Baron Palles from the Armagh Summer Assizes, 1899. The plaintiffs were the Rural Sanitary Authority for the Rural Sanitary District of Armagh Union. The defendant was the owner of a traction engine plying between Keady and Armagh. The plaintiffs issued a Civil Bill to recover a sum of £2 19s. 8d., being the amount of damage alleged to have been done by the defendant's traction engine to a main water pipe, and a sewer pipe, both the property of the plaintiffs, and laid under two streets in the town of Keady, and for negligence in the management of the traction engine. The County Court Judge dismissed the case on the merits, and the plaintiffs appealed. The appeal came on for hearing before Chief Baron Palles at the last Armagh Assizes. Chief Baron Palles found as facts:—

"(1.) That the damage complained of was done by the traction engine.

"(2.) That the defendant was not negligent in the management of the traction engine.

"(3.) That the water pipe and sewer pipe were laid at a depth below the surface of the streets sufficient to protect them from ordinary traffic, but not from injury by the defendant's traction engine."

The question reserved for the Court was—Whether upon the facts hereinbefore stated the defendant is liable to the plaintiffs for the damages done by his traction engine to their water pipe and sewer pipe.

Found "that the dismiss by the County Court Judge was

entirely wrong; and that the plaintiffs were entitled to decree for the amount sued for, and he would allow tl plaintiffs their costs."

DUBLIN GAS COMPANY *v.* COUNTY COUNCIL.

The most recent action is that of the Dublin Alliance an Consumers' Gas Company against the Dublin Count Council, which was for an injunction "to restrain the defe dants from using or causing to be used any steam or oth roller in such a way as to fracture, damage, or injure tl gas mains, service pipes, or other works of the Compan and for damages," and was tried before the Master of tl Rolls in March last. The Company alleged that the pipes had been broken at several places by the action of tl defendants' steam-roller in the repairs of the streets, & The defendants pleaded that the plaintiffs' works were n properly constructed, and that the pipes were laid too ne the surface. The Master of the Rolls was of opinion, as matter of fact, that the pipes were laid, though not so dee as more modern engineers would require, sufficiently dee to bear the ordinary traffic of these roads. He granted tl injunction, but disallowed the damages as the injuries we trifling.

From this decision the County Council appealed; tl Court of Appeal upheld the decision of the Master of tl Rolls, but varied it to this extent, that the injunction w only to have reference to the pipes of the plaintiff compa laid prior to the date when steam rolling was first used in tl locality.

The decision in the first case quoted, "Powell *v.* Fall seems to be a reasonable one: it is certainly incumbent the user of a traction-engine or steam-roller to preve injury to property by sparks issuing from the engine. Tl justice of the decisions in the other three cases does n

seem quite so clear. In circumstances similar to those which gave rise to the case, "Galer *v.* Rawson," the driver of a very timid horse ought to be held guilty of contributory negligence in taking out such an animal on a public highway, because a very timid horse may itself be, to use the words of the decision in "Powell *v.* Fall," "a thing of a dangerous character." With reference to the two remaining cases, it would seem not unreasonable to demand that the term "ordinary traffic" be interpreted so as to include appliances which are necessary for the efficien construction and maintenance of public roads.

Mr. G. M. Harriss, through the Hon. Secretary, desired to make the following remarks, being unable to be present to hear the discussion on Mr. Buckley's most interesting paper:—

Being an Electrical Engineer in charge of a station for the public supply of electrical energy, his interest in anything likely to occur to the roads was very considerable.

In Bray, where some 30 miles of electric mains are laid in soft ground, a great deal of steam rolling has been done recently, but in no single case did the mains suffer.

It did not need knowledge beyond that of the ordinary observer to be able to fully appreciate the enormous advantages of steam road-rolling, but to those who have opened trenches in a road before the passage of the roller, and again after, the advantages would be brought home very forcibly and unpleasantly, if, in estimating, a very liberal allowance had not been made for the changed condition in the latter case.

It was surprising the depth to which the roller affects and solidifies the ground, and it was striking that so much could be accomplished in a very little time.

Mr. Buckley's remarks *re* contour were interesting, and the

simple rule set forth would doubtless be appreciated *re* ope ing of trenches with scarifiers. This may, or may not, new to most of the members, but certainly it was new to hi and he would wish to thank Mr. Buckley for the informati under the above heading.

In conclusion, he would like to ask Mr. Buckley—

(1) What weight of roller he prefers?

(2 Would he think it of advantage to use two rollers one of from 6 to 7 tons, to be followed by one of from 10 12 tons?

(3) Does he think that, as time goes on, the weight the roller will be very much increased, and what would the maximum weight he would expect, assuming the crossi of bridges had no effect in limiting the weight allowabl

Mr. J. H. Moore said, with reference to what the auth said about "The relative cost of maintaining a road . . the expense which has to be incurred in supplying materi to form a proper section by the aid of a steam roller for ordinary macadam road, which has never been rolled befo has deterred many authorities from more widely availi themselves of the advantage of steam rolling. In near every case the old roads have a concave, tranverse sectic which is, as a rule, much more pronounced when the ro has a longitudinal inclination, and, in consequence of th the centre or crown of the road has to be raised a conside able height, often as much as twelve to fifteen inches, order to ensure that all the water which falls on the ro may reach the channel courses."

There were a great many roads in Ireland which had very respectable cross section, and which are not hollow the centre, and consequently would not require the en mous amount of material to be used upon them which t author had suggested.

These roads could be very much improved by rolling in the ordinary annual supply of material. He had read a very interesting paper by Mr. Hooley, County Surveyor of Nottingham, published in the "Proceedings of the Municipal and County Engineers," Vol. XXII., 1895-6, in which he advocates the system of rolling in the ordinary year's supply of material, which seems to be the practice in the County of Nottingham.

He thought it would be quite impossible to get the Rural District Councils to vote the large sums which would be necessary if such large amounts of materials were required for steam rolling.

He had persuaded the Rural District Council of Dunshaughlin to allow him £45, which he expended on the Ashbourne-road. This road had been about as bad a road as could be found. It was made in 1822 as a coach road to Londonderry. It had no foundation, was on a clay subsoil, and had been repaired for years with pit gravel. The ordinary specified quantity of material was about half a cubic yard to the perch, the width of carriage way being 21 feet. The roller worked 25 days in November, 1899, and rolled in this quantity for about 1,300 perches at an average cost of about 8d. per perch for rolling, exclusive of cost of stone and spreading.

The traffic on the road is principally hay carts, which go in trains of 30 to 40 carts, making long drills in the road. The effect of the rolling was something marvellous. The drilling was stopped and the road was free from loose scattered stones for the rest of the year.

This year he persuaded the Council to employ the roller again, and started a month earlier, and had not the least doubt that the effect would be better than on the first trial.

In proposing works of this kind the proper thing to do was not to frighten the authorities by asking too large an

amount. Steam rolling was of great advantage, for peo] would not stand having large quantities of broken stoı being laid on the road to be ground in by cattle, hors carriages and carts.

The steam rolling which they had seen adopted in t city of Dublin left a great deal to be desired. The stoı were not broken small enough. They used a great deal mc binding material than was necessary, and they generally us clay or mud for that purpose. After about a year the ro was as bad as ever. They had examples of that in Gardin street and that district. In Gardiner's-place the wh surface was covered with clayey sand about one inch thi rendering it absolutely impassible for cyclists in wet weath For some time after it had been rolled no patching went o and very soon again the roads got as bad as ever. If t ordinary metal was rolled in once a year the roads wou always be in good condition.

In some places they used the accumulation of ro scrapings for binding. All this mud had been swept off great expense, and it was thrown on again, and made very bad binding material, and only created more mud.

Mr. Dick enquired what was the general weight of stea rollers in use, and what weight did Mr. Buckley recommer

Mr. Buckley said:—When steam rollers were fi constructed they were made very heavy—some of the 30 tons. But experience had taught the users of the that it was really dangerous to put such heavy rollers ordinary roads. They would break almost every pi underneath the surface unless they were very deep. Th found that a roller of from ten to twelve tons was the bes there were some even as small as five tons. Of course Rural Districts they could use a fifteen-ton roller wi safety. In cities where there were a great number

pipes, especially gas pipes, it would be dangerous to use a fifteen-ton roller. In such cases a ten-ton roller was generally used.

THE PRESIDENT said they were all very much obliged to the author for his paper.

The subject was having a great deal of attention just now. Roads in the past were always considered of great importance. But they were looked upon as secondary when railways were introduced. Then when the bicycle and the motor car came the condition of the roads was brought to the front again. Those who ride bicycles are continually writing if they can find any cause for complaint. The roads must be to their satisfaction.

Of course, as they were all aware, the method used all over Ireland until very recently was merely to throw loose stones on the road and allow the horses and carts to grind and consolidate them. Since the passing of the Local Government Act and the introduction of steam rollers, every person even in remote districts was striving to get the steam rolling extended to their parts; having seen the good results obtained from it in other places.

He quite agreed with Mr. Moore in saying that when they had to approach Local Boards, especially in country districts, it was always advisable to make the expenses as small as ever they could.

He had been asked to give in a Report to his authorities as to the probable cost of rolling a road in his district, and the following was an extract from the Report:—

(Extract from Report from Edward Glover, Esq., County Surveyor of Kildare, to Committee appointed by County Council to deal with subject of steam rolling roads.)

"5th May, 1900.

"As, of course, you are aware, the method of road repairs

in this County is to spread material for the pass traffic to consolidate. But in many places (includ parts of Ireland) steam rollers are used for work, and any person who has travelled over a rolled r to which proper attention is given can have no doubt wh system gives the better results as to surface and comf in travelling generally. It is impossible to have good ro without good material, and this applies with special fo to steam-rolled roads. No limestone is suitable for rea heavy traffic roads, rolled or unrolled. From inquir and observations I know that imported stone often as hi as 9s. per ton is mostly used in many places in preferei to local stone at 4s., and gives in the end cheaper resul But the large majority of Kildare roads have not rea heavy traffic, and the limestone in this county from grav pits or broken to proper size is very fair. Some lo quarried stones, especially in Celbridge district, are, ho ever, unsuitable. Proper stones are those from t igneous rocks, such as hard granite or syenite; and m of the beautiful roads we hear of in Wales, England a other countries have such stones, or those of allied ch racter, rolled in. Inferior stone is liable to be crush and pulped by a roller, and in addition it wears badly, giv out dirt and dust, and forms into holes and ribs where hea carting goes—or indeed under the quick traffic of plac much travelled by the 'Irish Jaunting Car.' Parenthet cally it may be observed that the narrow wheel tyr almost universally used in Ireland for heavy weight traff are very hard on roads, and a great deal of the complain about roads in this country are due to such tyres.

"Steam rolling may be viewed in two aspects—(1) Coa ing and sheeting a road all over, and (2) patching. Prob ably a third aspect might be added which consists in rollin and consolidating an existing road surface without spread

ing any or scarcely any material at all, but merely to pick and level surface before rolling.

"COATING AND SHEETING A ROAD ALL OVER.

"Assuming, as I think we may, that our local limestone (except in Celbridge and Leixlip neighbourhood) is very fair, there are several lengths of roads upon which coating and sheeting could be done with the local stone. In such work a steam roller will roll about 35 to 40 tons a day, say four inches thick finished, and a ton will cover about seven square yards. Assuming a road 21 feet wide, one ton of stone will do for about one yard in length of the road, so that one mile of such a road would consume about 1,760 tons. Assuming 3s. 6d. as the average price for limestone delivered, we see that material alone will cost per mile over £300. The rolling of such a thickness would take about 50 working days, at £3 5s. per day, which for rolling alone is over £160. Thus laying on a steam-rolled crust of local stone four inches thick would cost in this country about £460 a mile. If a coating one stone high were used and finished off about two inches thick over a 21 feet wide road, the cost would be roughly half of above figures—probably a little over £200 a mile at the rate of about 12s. 6d. a perch.

"But such a thin coating would soon require renewal or extensive repairs by patching, where traffic is at all heavy, in the following year. It is a mistake to think that steam-rolled roads will mind themselves for a considerable time. Rolled roads, especially if thinly coated, get into ribs and small hollows, and must be patched and cleared periodically. It is generally agreed that there is a saving of at least 25 per cent. in material by adopting rolling, even in coating one stone high, and this with far better roads is an important thing. But coating

a road all over is so expensive even with local stone that, except in some very special cases, it cannot probably be much adopted amongst us. We therefore turn our attention to aspect No. 2 above mentioned.

"PATCHING.

"This method assumes only the ordinary quantity of material, and should answer for most of the roads in Kildare upon which the heaviest traffic is. About 90 per cent. of the material could be rolled in at one operation, and the remaining 10 per cent. left to maintain the road for the rest of the year by spreading, &c., in the ordinary way. A steam roller will do patches amounting to 120 tons, one stone high in about 8 days, or a mile of road costing about £27, and I believe much of this cost would be saved in less labour (than under the existing method) for the rest of the year. Many roads in Kildare have over 150 tons a mile a year regularly applied to them, but of course patching could be done with any smaller or greater tonnage at less or greater expense. This method I think would give better roads with very small extra cost, if any, at the commencement, and probably less cost than under the old system very soon. It may of course fail in some particular cases from shortness of material, but it seems to be the system which Kildare might try even if only in a small way.

"Without any material at all, and especially where the crust is thick, the mere act of picking and rolling will so consolidate and shape a road that great improvement results. The cost of rolling this way would be about £10 a mile. The best time for steam rolling, especially for patchwork and consolidating, is during long-continued dry weather, so as to allow the surface to harden by evaporation. Generally for all steam rolling the three winter months are bad—frost especially neutralising every benefit from rolling if it comes on soon after the work is done.

"Steam rollers can now be easily hired, and one or more experiments if thought advisable can be easily made upon suitable selected spots."

The result of that Report was that he got the steam roller on hire, and spent the sum of £50 on about 2½ miles of road. He used about 300 cubic yards of material, and it cost him about £50 to roll it in. The effect was very satisfactory.

In the rural districts of Ireland they would find there were a great number of the roads with fair bottoms, and when this was the case they would find the best plan was to adopt the method of patching the road, using the ordinary quantity of material. Of course materials were nearly all the cost in works of this kind.

The first work he had carried out was so successful that now he had got the sum of £100 to expend on another district.

They could get a great deal done in this way if they did not frighten the ratepayers by asking too much.

There was no doubt steam rolling improved the roads very much, but some people would tell them if the roads were properly and regularly attended to they would not need rolling.

He believed there was something in that. If the material was broken up small, and the roads kept clean, with the surface properly softened, they would have really good roads, practically as good as rolled roads.

With reference to the breakages of pipes, &c., unfortunately it was impossible to prevent the owners of traction engines from doing this, and they followed the same rule as steam rollers. They might put up notices on bridges that they were only suitable for ordinary traffic, yet the engines went over them, and you could not stop them.

Last month he had a case of a breakage by a traction

engine in the road over which he had control. After repairing it he sent in his bill of costs, but before he could get a reply the very same engine made another breakage in the exact spot where it had just been repaired.

This traction engine had a 7 foot 6 inch driving wheel, and weighed about 20 tons.

He sent in his bill for the second repairs, making the amount a little more. The owner had agreed to pay the first bill under protest, but he absolutely refused to consider the second bill. He wrote, "There was some excuse for the first break, but when it was repaired it should have been made up to date."

He also said, "That it was the law of the land that 30 tons was the legal load upon Irish roads."

This law would be new to some of the members. He had written in reply to the owner, "That he could carry 300 tons on Irish roads if he liked, provided he did not carry it on one axle."

Of course the case would be tried out at the Law Courts, for the County Council would go to law on the point.

In the towns in his district the gas pipes were put extremely near the surface, and the question of the roller did not apply. He saw a gas pipe the other day which was fractured by a passing traction engine. It was simply made into a syphon.

Mr. Buckley, in reply, said, with reference to what Mr. Moore said about the large quantities of stones he recommended, of course it was not always necessary to put down this enormous depth, for he had mentioned in his paper that "In the case where a road had been repaired for a number of years with greenstone, and which in consequence has a superficial layer of good metal of fairly uniform thickness, an excellent surface may be obtained without incurring the cost of any new material by scari-

fying a few inches deep over the entire surface, moving if necessary from the sides a little of the loose material thus obtained, and then rolling."

In the district of which he happened to have charge he had found the roads in a very bad condition, for the very simple reason that very little material had been put on them. One reason for that was the very strong objection there was to have loose materials put upon the roads. In Rural Districts loose stones would be tolerated to a greater extent than in Urban Districts because the traffic was different. They had heavy agricultural traffic in the Rural Districts which very soon crushed the loose materials on the roads. Whereas in Urban Districts they had light vehicular traffic, and cyclists, who would be up in arms if any loose stones were left on the road. Another difficulty he had to contend with was the paths on both sides of the roads, some of which were very high, and necessitated more material to bring the road to the proper relative height of the path.

In reply to Mr. Harriss, there would not appear to be any special advantage in using a roller of less weight than nine or ten tons in the formation of ordinary roads. Nor is there much probability that the weight of the roller will be very much increased beyond the present maximum so long as the present practice of laying down pipes for the conveyance of sewage, water, gas, electricity, &c., is continued. A very heavy roller would crush soft stone like limestone to dust. This would be very objectionable in laying down the topmost layer of a road formed entirely of such stone.

Mr. Kernaghan, through the Honorary Secretary, said:—At Drumherriff Drainage Works, Co. Leitrim, the rock was bored 200 feet on each side of the boiler, the steam carried by 1-inch piping to the drill, the pipes covered by hay rope and mud; 400 feet of cutting could

be done before the boiler need be moved. A $2\frac{1}{2}$-inch bit was used. The average boring, including several shifts, was 40 feet per day, and a maximum of 56 feet with seven or eight shifts.

The drill worked at, I believe, 300 strokes per minute.

The cost of boring a $2\frac{1}{2}$-inch hole was between 4d. and 5d. per foot, including all cost of labour, oil, coal and proportional establishment charges.

The rock was of a very hard, gritty nature. The average cost between hand boring and steam drill boring was 6·28d.

The explosives used were gelignite, tonite and blasting powder. For quantities see the following Table showing comparison with some European railways given by Eister:—

—		Formation	Black Powder	Dynamite	Bickford Fuse	Caps
European Railways	1	Gneiss, fissured, 15,896 cub. yds.	$1\frac{1}{2}$ oz.	$0\frac{2}{10}$ oz.	0 ft. 2 in.	0·025
	2	Gneiss and granite, middling hardness, 44,131 cub. yds.	$1\frac{1}{2}$ oz.	$1\frac{1}{2}$ oz.	1 ft. $0\frac{3}{4}$ in.	0·30
	3	Granite of middling hardness, 21,615 cub. yds.	$1\frac{2}{10}$ oz.	$2\frac{3}{10}$ oz.	1 ft. 2 in.	0·28
	4	Hard granite, 14,248 cub. yds.	$1\frac{3}{10}$ oz.	$2\frac{3}{10}$ oz.	0 ft. 10 in.	0·25
Drumherriff Works.		Old red sandstone, hard compact, 15,000 cub. yds.	$0\frac{2}{3}$ oz.	Tonite, &c., $2\frac{4}{10}$ oz.	1 ft. $1\frac{1}{2}$ in.	0·39

Excavated nearly 18,000 cubic yards at a cost of 4s. per cubic yard, viz. :—

	£	s.	d.
Quarrying and removal -	0	2	3·84
Boring - - -	0	0	6·28
Smithwork - - -	0	0	0·90
Unwatering - - -	0	0	3·66*
Explosives - - -	0	0	3·46
General, including dams -	0	0	5·54
	0	3	11·68

* The heavy unwatering charges are due to special circumstances.

[5th December, 1900.]

Annual General Meeting.

Mr. Edward Glover, President, in the Chair.

The Officers of the Institution for the year 1901 were balloted for and duly elected (see List of Members).

The following Candidates were balloted for and duly elected:—

Mr. Matthew Fortescue, as Member; Mr. Hugh Stanislaus Hurley, as Associate Member, and Mr. Edward P. Nolan, as Associate.

The President delivered his address as follows:—

Gentlemen,

I thank you sincerely for electing me your President, which is the most honourable position that any engineer practising in Ireland can hope to reach. This being my opinion, I feel that your President's responsibilities are heavy, and I ask your kind indulgence for shortcomings on my part while I occupy the position as official head of the profession in this country. I also crave your help in making the coming session a successful one. I know from experience that your Council have only one object in view—namely, the benefit of this Institution and its members. I believe we are progressing and expanding, and there can be no reason why we should not continue to do so. But our well-being and influence chiefly depend upon the members themselves. And there are many directions in which members can act for this old Institution—such as preparing papers, attending at our meetings and joining in discussions, getting qualified men outside

to become members—to say nothing of joining our Dinner Club, and thereby producing somewhat approaching social intercourse amongst members. Other ways of strengthening the Institution will easily suggest themselves. Every one of us comes across matters in the routine of our daily work which, if reported here, would be most interesting and instructive. A well-kept diary, the pay sheets and detailed observations regarding any contract executed, no matter how small, would be valuable, so that there can be no real want of interesting subjects to write papers about. Many members are, perhaps, disposed to feel that communications read here should be concerning some large or novel undertaking, and if showing new practice behaves in obedience to formulæ the better. But no greater mistake could be made. It is our most common experience to find no full details in engineering publications, for scores (I might say hndreds) of the small jobs which turn up every day. In laboratory practice no experiment on the full size natural scale) be considered too executed work of an engineer (we may truly call it an experiment on the full natural scale) be considered too trivial for detailed records and registration? Another thing I believe is that we should all now and again present to the Institution copies of the drawings and specifications relating to some of the works carried out by us, especially for the sake of our younger members. We should strive and make the knowledge of everyone of us available to every other member. As regards striving to increase our numbers, we should not be canvassing for members, of course, but every qualified engineer in Ireland should join this Institution, which is the only Irish authority that can pronounce upon an engineer's qualifications. No doubt there are Universities, Science Colleges, &c., &c., which give degrees or licences, but except this

Institution no authority in Ireland can pronounce upon a man's fitness as a practical man. All methods of training for our profession, whether partly in a University, or wholly by apprenticeship, are but a preparation for admission to our ranks. I go so far as to say that no man's qualifications can be properly scrutinised and pronounced upon as an engineer except by Institutions like ours. We should, therefore, value our membership, and at the same time look upon the qualifications of every outsider as non-proven, unless, of course, he belongs to an Institution of some other country or place similar to ours. Whether the Registration of Engineers will ever become law it is hard to say—it would seem a desirable thing only for the necessary inclusion of existing unqualified persons. It seems more than probable that as education advances and Institutions like ours exert themselves, registration will become unnecessary. There are already evident signs that public opinion and public boards are getting to know that any person may, if so disposed, place C.E. after his name, and that these letters are evidence more of disqualification than qualification. I believe the time is approaching when, either by registration or evolution, the camp followers and parasites of our profession must disappear, and that this Institution should be the Irish centre for examining evidences of qualifications and issuing final diplomas to candidates in Civil Engineering. The recent change in our bye-laws constituting an Associate Member class was long needed. I look forward to good results from the change, and even already we have reaped benefit from it. It is usual for your President in his address to refer to some of the passing events of the day, and more especially to Irish ones, which affect not only the country but our members. Perhaps no subject within the last twelve months has called for more attention than the

recent Local Government (Ireland) Act, which came into operation on 1st April, 1899, and it is my intention this evening to say a few words about it, from the point of view of one in charge of public works, working the Act, and as it affects our members, and as I believe it will affect our country. Another Act of Parliament much talked about—namely, the Agricultural and Technical Instruction (Ireland) Act—came into operation on 1st April, 1900. It has to do with the agricultural and industrial development of Ireland, under the control of an entirely new Department, having at its head a Minister directly responsible to Parliament, and aided by a Consultative Council representative of the interests affected. The Legislature have placed moneys at the disposal of the Department, and local public bodies can contribute within certain limits towards the expenses that may be incurred in furtherance of the objects which have received Parliamentary sanction. This Act must open a new era for this country, when agriculture and industry are now directed by the State. Indeed the wonder is that the Act was not passed long ago, when we consider what has been done in most places in Western Europe. This Act should have a peculiar interest for engineers, for as it develops there must be occasion for our services; and it should be, and I am sure will be, our business to watch developments in the interest of our members, and even at the present stage to bring under the notice of the new Department that we have amongst us specialists in all engineering matters relating to surveys, drainage, reclamation, and industries. The Department, in dealing with live stock, will, I am sure, consult veterinary surgeons, and I assume that, in a similar way, engineers will be called upon for advice on matters relating to the direction and execution of work, whether as regards agriculture or industries. I go further

and say that a regular engineering staff should be attache to the Department, to be supplemented in time of pressur if there is to be any marked and continued improveme upon the present state of things. From what we know Mr. Horace Plunkett, the Vice-President of the new Sta Department, and of Mr. Gill, we may feel sure that the will do the right thing. But my remarks this evening a to be principally on the Local Government (Ireland) A saying a few words about its working as well as the resul which I think must follow from it, indirectly as well directly.

As can easily be understood, the Act is a compl one. Its authors had a huge task, and their labours be evident signs of the wish to keep the mean between t two extremes of too much stiffness in refusing and of t much ease in admitting variations, from what experien in the past proved good and applicable, although, perha under circumstances not quite the same as will be in t future. Hence, in addition to the new matter in the A we find "adaptations" of existing Irish enactments a the "application" of English and Scotch ones. Towa the end of 1898 the public papers opened their columns legal gentlemen and others who wished to explain the and show how other Acts were welded on to it. A serie articles appeared in the Press by Messrs. Muldoon McSweeny, Barristers-at-Law. These articles were af wards printed in book form, a copy of which is in possession, and I think I cannot do better than quote h the "Introduction" to the book which was published October, 1898, or about six months before the Act c into operation. The "Introduction" shows not only administration of local affairs under the old system, also what the new Act substitutes therefor.

Messrs. Muldoon and McSweeny, writing in 1898, just after the Act passed, say:—

"In order to appreciate the changes introduced by the Local Government (Ireland) Act, 1898, and to help to a better understanding of its application to Irish county government, it may not be amiss to briefly review the system, or rather systems, of administration of local affairs in this country, which the new system is intended to replace. The powers now exercised by the various Local Government bodies have been heretofore divided between such utterly divergent authorities as the Grand Jury, the Poor Law Board, the Board of Works, the local magistrates, the Lord Lieutenant, and the Sheriff.

"Generally speaking, the Grand Jury had charge of county expenditure. The Grand Jury is an institution of remote constitutional origin. Introduced into Ireland after the Conquest, it gradually gathered to itself the extraordinary combination of duties which disappear with the present Act, leaving only its original criminal jurisdiction unimpaired. The fiscal powers of the Grand Jury in England practically ceased to exist nearly two centuries ago. In this country not only were they not made fewer in the lapse of time, but were increased, strengthened, and consolidated by enactments of Parliament, coming down almost to our own time. The modern Grand Jury system was established by an Act passed in 1836, which, indeed, is the principal Act under which Irish counties have hitherto been governed, and some of the provisions of which will still have to be applied in the administration of the present Act. The Grand Jury is selected by the Sheriff of the county for the time being, the Sheriff himself being appointed by the Lord Lieutenant. In selecting the Grand Jury the Sheriff's discretion is fettered by only one statutory rule—namely, that he must place upon the

list the name of one person from each barony holding fre hold lands to the value of £50, or leasehold lands to tl value of £100, above the rent. After this rule is satisfi no qualification whatever seems to be necessary for tl other grand jurors. The body has no continuous corporate existence. Once discharged by the Judge Assize, it ceases to exist for any purpose, and its respon bility ceases with it.

"The Presentment Sessions, now abolished, were call in each barony previous to the assizes, and were compos of the local justices and a number of cesspayers select from a sort of panel of the highest payers of county rat prepared by the Grand Jury at the previous assizes. It v the duty of these sessions to first consider presentments works, &c., which subsequently came for ratification rejection before the Grand Jury at the ensuing assiz Besides this a County-at-large Presentment Sessions c sider presentments, the expenses of which are chargea against the county as a whole. The business of the Gr Jury comprised besides the public works of the cou which included the making and repair of roads, bridges, construction and maintenance of courthouses, the cou printing, and the administration of a number of statu Besides this they were obliged to levy rates off the cou for the support of lunatic asylums, county infirma industrial schools, coroners, certain constabulary char the conveyance of prisoners, guarantees to railway tramways, and some other less important matters, dow the payment of court criers and tipstaffs.

"Besides presentments for works and expenses of kind enumerated, the Grand Jury had to consider cl for malicious injury to property, and criminal injurie constables or witnesses, sustained in consequence of t action in making amenable persons accused of cr

These functions are the only ones of the Grand Jury taken away which will not pass to one or other of the bodies created by the new Act. The only check upon the action of the Grand Jury in making presentments was the traverse before the going Judge of Assize. Under the new system the traverse entirely ceases, as does all power and jurisdiction of the judges with regard to the general county expenditure. Malicious injury applications will, on the other hand, be in future decided by the County Courts in the form of an action against the county, with the same right of appeal to the assizes as in the case of ordinary processes, and an additional discretion by the judge on appeals to empanel a jury to try questions of fact.

"The second element in Irish Local Government, as it hitherto existed, is comprised in the great group of powers vested in the Local Government Board and the Boards of Guardians under the Poor Law system. Originally constituted by an Act of the first year of the Queen's reign, for the sole purpose of relieving paupers in workhouses, the Poor Law system has, during the sixty-one years of its existence, gathered to itself a great variety of powers. There being no other local bodies in the greater parts of the rural country districts in Ireland, Parliament adopted the simple expedient of transferring the administration of any new statutes to either the Grand Jury or the Poor Law Boards. As the Grand Juries met but twice a year, and then only for a short session, the greater burden fell upon the guardians. From being the mere guardians of the workhouse they became the public sewer-makers, the custodians of burial grounds and wells, the constructors of waterworks, the proprietors of dwellings for labourers, the executors of compulsory vaccination laws, and the laws relating to the sanitation of dwellings and public nuisances, and the repositories of a number of other powers down to

the muzzling of dogs and the slaughtering of diseased animals. The guardians exercised their powers under the control of the Local Government Board.

"Each board of guardians was partly elective and partly ex-officio. The latter element comprised half of each board, and consisted of the justices of the peace residen in the union, and if these proved insufficient to complete the number, a certain number of non-resident justices hold ing property in the union was added. The elective elemen of the board was elected by the votes of the ratepayer and owners of property. Every ratepayer had at least one vote, and the number of votes increased according to valuation and other conditions in a most complex manner The owners of property had similarly plural votes, the general maximum being six, but under the system it wa possible to have combined in one voter qualification entitling him to cast 36 votes in a single electoral division The change under the new system, in which not merely every ratepayer, but every occupier and lodger, whethe rated or not, will have a vote, and no person, howeve great his property or liability to rates, will have more tha one, is, therefore, revolutionary. There will not in futur be any election of guardians, as such, except in th boroughs and other urban districts; but each distric councillor will be the guardian for his own electora division, and the ex-officio element, in the old sense of th word, will entirely disappear. As the Grand Juries raise the county cess for county purposes, the Poor Law Board levied poor and other rates for the purpose of carrying o the administration.

"The powers vested in Corporations and Town Com missioners in Ireland have been derived from various publi and private Acts of Parliament. The Act of 1828 (9 Geo IV., c. 82) gave a power of constituting Boards of Com

missioners for municipal purposes, to levy rates, and to apply them to purposes set out in the Act. The Municipal Reform Act of 1840 and the Towns Improvement Act of 1854 are the principal public Acts for the local government of the cities and towns. The Municipal Reform Act abolished a large number of municipal corporations which up to that time had existed, but provision was made for the establishment of municipal bodies under the Act of the fourth George above referred to, and empowering the citizens, if they should prefer it, under certain regulations, to apply by petition for the grant of a charter. The Public Health Acts enabled the Local Government Board to constitute municipal towns urban sanitary districts, and conferred extensive powers as to sanitation generally. By the Public Health (Ireland) Act, 1896, these powers can now be conferred on rural authorities.

"Having thus summarised briefly the previous condition of local government in Ireland, let us glance shortly at the new system which the present Act substitutes for the old. Section 1 of the Act establishes in every administrative county a County Council, consisting of a chairman and councillors. To this Council is transferred all the fiscal business of the Grand Jury, with the exception of the power of making presentments for malicious injury, which passes over to the County Courts. The presentments of the Grand Jury had to be formerly approved of by a Judge of Assize. This fiat is now abolished. Besides the powers of the Grand Jury, the County Council will have the power of the Board of Guardians with respect to raising and levying the poor rate—in other words, all the rates in each county for the future will be raised by the County Council in one general rate. In addition, the County Council will have transferred to it the administration of the Diseases of Animals Act, the Explosives Act, the Acts

relating to Technical Education, and the management (lunatic asylums, including all the powers of the Boar of Control which is abolished. Upon the County Counc is also conferred large powers for acquisition of land fc county purposes, and a number of other duties and powe to be considered hereafter in detail. The new counci thus constituted will be elected by Parliamentary electo for the county, with the addition of women and peers, wh are qualified in other respects, and the elections will be b ballot. They will all hold office for three years, and the go out in a body.

"For the discharge of the business of the more circum scribed local areas within the county, subordinate bodie called District Councils, are established. These are divide into two classes—Urban District Councils and Rural Dis trict Councils. Where there is an urban sanitary authorit at present existing, an Urban District Council will b formed, and this Council within its own area will have a the powers of the Grand Jury with regard to roads, &c. and will raise its own rates, while being subject to som general control and answerable for certain contribution to the County Council. In the areas where no urba sanitary authority exists, rural districts, governed by Rura District Councils, will come into existence. The rura district will, as far as possible, correspond with the existin Poor Law Union, and will be composed of councillor elected on the same franchise as the members of the Count Council, two members being elected for each electora division now electing one guardian with an increase number for electoral divisions or wards which now elec more than one guardian.

"The district councillors for each division will also b the guardians for that division, so that in the rural district there will be two distinct bodies consisting of the sam

individual members, but having separate functions. The District Council will have the powers heretofore possessed by the Baronial Presentment Sessions, and also will take over certain of the powers of the guardians. Neither these Councils nor the guardians, however, will have any power to make or levy rates, this being done by the County Councils, who will provide the funds for local purposes.

"Six boroughs, namely, Dublin, Belfast, Cork, Limerick, Derry, and Waterford, will become 'administrative counties' for the purposes of the Act. The Act, however, will not change the constitution of their Corporations, and will, practically speaking, only operate in two respects, (1) to give them any powers given to County Councils under this Act, and which they do not already possess, and (2) to extend the franchise."

To the foregoing may be added, that by the Act where any town has a population exceeding 1,500, according to last Census, but was not an Urban Sanitary Authority when the Act passed, such town may, by following certain procedure, become one, and must appoint a town surveyor. Several towns have already become urbanised and have now their own surveyors.

The County Council is the authority for public works—a public work being defined in the Act to mean any work in respect of which, under the Grand Juries Acts, a presentment might be made by any presentment sessions for a barony or county-at-large, or any Grand Jury.

Although County Councils are the authority for roads and the various works connected with them, they have no power to decide as to what work is to be done, or to say what the cost is to be. Neither can a County Council pay money to a contractor unless sanctioned by either a District Council or Proposal Committee. A County Council can only approve, reject, or modify any proposal for a work or a payment

coming before them; and in the case of modification the matter must be returned to the body where it originated to be reconsidered. And this brings us to the duties discharged as regards public works by the District Councils (rural and urban) and the Proposal Committee, where the proposals for expenditure must begin. In this place it may be interesting to know that in 1834 there were under repair by the Grand Juries in Ireland 13,191 miles of road at an annual cost of £228,316. I have no official return of the mileage of county roads later than one made out for the year 1885, when there were 51,182 miles under contract. Most probably the mileage at present is about 52,000 miles. From Appendix (L.) it will be seen that the average yearly expenditure on roads during the three years next before the passing of the Local Government Act was £775,212. The office of County Surveyor was established in 1834, and a comparison of the above figures will show what great saving has been the result. Taking the 1834 figures, if the cost per mile had been maintained and the increased cost of labour added, the road expenditure in Ireland would at the present moment be at the rate of over half a million pounds sterling per annum greater than it is.

By the Act expenditure for roads in Ireland cannot exceed by more than 25 per cent. the average of the three years referred to. In Appendix (I.) will be seen figures on this point for the whole of Ireland; and the limit of expenditure may be taken approximately at £1,000,000 sterling.

All Councils conduct their business according to orders in Council as well as regulations and instructions issued from time to time by the Local Government Board. Taking the Act as it is, I think there is reason to be well satisfied with the manner in which, upon the whole, it has been worked by all the Councils throughout Ireland. Many hitches, of course, have occurred, and no wonder; but it should be a source of

gratification to all Irishmen to know that the new public bodies in this country have, as a rule, taken up and discharged their new duties in a businesslike and workmanlike manner. Much of the success in starting and working the new Act must be attributed to the Local Government Board. That Board, in my opinion, has done its best to be the guide, philosopher and friend of Councils in working the Act. Not only does the Board anticipate future difficulties or requirements by issuing instructions for guidance, but answer with the most patient care every question addressed to them by officials as well as by Councils. My experience relates to the Surveyor's Department, but I believe I am right in saying it applies to the other departments of county government as well. It may, I suppose, be taken as an axiom that a Local Government Board containing highly trained experts is absolutely necessary for county government.

Here in Ireland we are accustomed to read of decisions by our Local Government Board being commented upon—indeed very often sharp things are said about the Board being high-handed, despotic, &c. I believe the Board does its very best for the interest of the country, of those who pay rates, and of those who own or occupy nothing of any value to pay rates for. For the sake of the country the decisions of the Local Government Board should always command as much acquiescence as the decisions of any court of law, if not more, seeing that the Board (excepting for criminal cases) has to deal with greater interests than any judges or magistrates. How is this desirable acquiescence, on the part of a defeated party as well as the victorious party, to be brought about? The answer, I think, must be to strengthen the Board by the addition of an elected factor. An Irishman is very full of sentiment and almost loves a beating if any man of his own selection had a hand in it.

Returning to District Councils and Proposal Committee,

where proposals for public works must be formulated, it is to be noted that for the consideration of such works meetings are held once a quarter. District Councils deal only with the area of their own district, whereas a Proposal Committee considers works in which the whole country is interested, such as a Courthouse.

A County District and its Council have replaced the old Barony and the Presentment Sessions, while the Proposal Committee does the same work as the old County-at-large Presentment Sessions. The financial year begins on the 1st April, and therefore the first, second, third, and fourth quarters of each year end on 30th June, 30th September, 31st December, and 31st March respectively. The County Council fixes dates of all quarterly meetings, including its own, but District Councils and Proposal Committees themselves arrange days for their adjourned meetings to consider tenders for works.

District Councils at their quarterly meetings consider applications for new works, which can be made by a councillor on notice of motion, or by the County Surveyor in his Report. The Councils also consider payments to be made to contractors for work done during the preceding financial quarter. A list of such payments is made out by the several clerks of District Councils (and, for county-at-large, by the Secretary of the County Council) and forwarded to the County Surveyor, who returns it with his recommendations regarding sums to be paid, deferred, or struck off. See Appendix (II.). The clerks of District Councils should have nothing whatever to do with making out the list of payments referred to, and procedure on this point should be changed. The District Clerks are not the custodians of any original documents relating to such work, they have to be deposited with, and kept by, the Secretary of the County Council. I am not aware if District Clerks will be held responsible if an

error is made in amount of money placed by them before a County Surveyor. Nor am I aware if a County Surveyor would be surcharged if he certified for a wrong sum so placed before him, say for £51 17s. 6d. instead of £51 7s. 6d.

All a County Surveyor can do is to say that work has been done or not done, or to what extent, but he can have no knowledge of the exact amount for each contractor, and must accept figures placed before him. These figures should be actually certified as correct by the proper officer, and that officer should be the Secretary to the Council. As it is the Secretary has to wade through all payments every quarter and compare them with original documents to see if errors are made in sums to be paid. This is beginning at the wrong end, and means more trouble and risk to the County Office than if the several lists of payments originated there were compiled from what should be a County Register and original documents, while it means, in its present working, a duty thrown on District Clerks, about which, as far as I know, an auditor or such like officer never questions them or takes any notice as to accuracy or inaccuracy on their part.

Tenders for works approved of at a quarterly meeting are opened at the adjourned meeting and contractors selected; the lowest tender need not be accepted, which is an improvement on the old law. If there is a work for which no contractor (or no proper one) appears, such work can be placed in charge of the County Surveyor. In some parts of Ireland the Councils object to setting road maintenance work by contract, and there has been recently passed an Amending Act—namely, the Local Government (Ireland) (No. 2) Act, 1900, which confers power upon the Local Government Board to enable Councils to employ direct labour upon roads. Direct labour, in the sense sought for by some counties, does not mean an isolated case here and there—for such is occurring every day—but the general

adoption of such labour over a large area to the entire exclusion of road maintenance by contract. Whether better results can be obtained from the contract system, or from a general adoption of direct labour, it is not necessary to discuss here at any length. I will merely say that I believe direct labour would not be as efficient or as economical as contract work upon roads at less than, as a rule, say £20 a mile per annum. And even upon high priced roads direct labour would lead to waste and loss unless upon a fairly large scale and such as could keep permanent gangs of men at work within easy distance from their homes. It goes without saying that all expenditure, the selection of workmen or their dismissal, should be on the same business principles as would be practised in private undertakings. I would not be against giving direct labour on above conditions a fair trial. It should be noted that the contract system cannot hope to be as efficient under County Councils as under Grand Juries, owing to three very serious changes made in the old procedure in the adaptation of Irish enactments. I refer (1), to 6 & 7 Wm. IV., cap. 116, sec. 54; (2), to ditto, sec. 128; and (3), to 19 & 20 Vic., cap. 63, sec. 17. Of these No. 2 has been repealed altogether. This section (128) in Grand Jury times provided that in cases where the cost of any public work exceeded £20, advances could be made to the contractor from time to time up to 75 per cent. if certified for by County Surveyor at any time. Advances cannot now be made, which is a great blow to the contract system. Again, under section 54, whenever (in old times) a County Surveyor discovered a road neglected, he could at once serve a ten-day notice upon the contractor, and if such notice was disregarded get road repaired out of money that would be due to contractor if he were not guilty of neglect. At present, owing to the manner in which 54th section has been adapted, a County Surveyor cannot proceed in this way. He must

report neglect to the County Council, and the Council must then meet to consider the report and authorise the serving of a ten-day notice. It is not necessary to say that the very day after the meeting of a County Council a fresh case of neglect might be discovered which would involve another meeting—and so on. Again, when Grand Juries were in being a County Surveyor could at once summon a defaulting contractor under 19 & 20 Vic., cap. 63, sec. 17; now by the adaptation of Irish enactments he cannot do so without reporting to County Council, calling a meeting, and getting authority. All this means delay, waste of time, attendance at meetings, and the very serious question of bringing Councillors together from every part of a county.

To give the contract system the same chance under County Councils as under Grand Juries, I believe the three sections referred to should be restored to what they were under the old law, otherwise I have great fears of how the system will behave in the future.

I do not know if those who undertook the duty of adapting Irish enactments consulted any one supposed to have special knowledge before setting about the task. In any case we find the following "adaptation" of section 80 of the Grand Jury Act of 1836:—"It shall be lawful for any County Council to resolve that any sum or sums of money shall be raised off the county-at-large. . . . for erecting or repairing direction posts. . . . or depôts for materials, not exceeding one pound for each direction post. . . . or depôt." This is a copy of the old section 80. One pound may have been sufficient for a direction post in 1836, but not in 1900, so the section may as well have been repealed. Again, £1 for a depôt might as well have been one shilling for all practical purposes. Be it therefore understood that according to law direction posts cannot be placed on Irish roads. Why a maximum sum was ever named it is hard to

say, anyhow the modern limit should be about £3. Again, as to depôts for material, probably the average size ought to be for about 40 tons, and would be, say, 30 feet by 9 feet and 6 feet high to prevent trespass upon land. The masonwork for such a depôt would cost about £12, to which should be added preparation of site and price of land, for no walls of depôts should extend beyond line of road fences. Future County Surveyors are to be examined by the Civil Service Commissioners as in the past, but the examination will not be competitive as it used to be, which is an evil and retrograde step.

Assistant Surveyors must have such qualifications as the Local Government Board may prescribe, and I give in Appendix III. the Order made by the Board on this subject. It will be seen that an Associate Member of this Institution is qualified for an Assistant Surveyorship without examination. This, I believe, is one of the good results from the manner in which your Council watched the interests of members during the passage of the Local Government Bill through Parliament.

District Councils, in addition to discharging the duties as regards public works, which formerly belonged to Presentment Sessions, are the sanitary authorities, and have all powers relating to sewers, water supply, public lighting, labourers' cottages, &c. I have heard it said by experienced persons that sanitary work should be administered by the County Council, but I do not see how it could work out in practice. Besides, such work is only of importance to a particular district, and not to the whole public at large. District Councils have their Engineer, who is paid sometimes by fees and sometimes by salary. I can find no prescribed regulations for this officer, although lately, and for the first time, I heard of where the Local Government Board asked for evidence of qualifications from a newly appointed Engineer.

All Urban Councils have complete control of their own district roads; but where main roads—half cost of which is payable by county-at-large—run through their district, such main roads are managed by the County Council. But Urban Councils may arrange with County Councils for the entire management of their main roads, upon getting such yearly sum as may be agreed upon. Urban Councils must, however, contribute to county-at-large charges, which include main roads throughout the whole county. Before the passing of the Act there were no "Main Roads"—every district (barony) was bound to pay the whole cost of its own roads except where a mail-car travelled. The authors of the new Act must have believed that two benefits at least would arise from the principle of main roads—(1), a better class of principal thoroughfares; and (2), the relief of poor or highly-taxed districts. It is hard to say whether this opinion is right or wrong as regards a better class of road. Some counties have already adopted a scheme of main roads, while others would have nothing to say to them, and left every District to pay its own whole cost. Others again have not yet finally decided in the matter. No doubt a scheme for main roads would result, as a rule, in relieving highly taxed Districts, so that the subject has been greatly discussed in some places.

The Surveyor to an Urban Council must satisfy the Local Government Board as to his qualifications, and provision is made for what we may practically call a Consulting Engineer as follows:—"The (Urban) Council may, with the sanction of the Local Government Board, employ a Member of an Institution of Civil Engineers or other qualified or competent person to prepare the Contract Drawings, Specifications, form of Tender and other documents, and superintend the construction of any public work within the district, in case the Council may not consider it convenient or desirable to require

their Surveyor to undertake the same." . . . The action of our Council, before the new Act became law, in addressing themselves to Parliament, to high officials of Parliament, and public departments having to do with the proper expenditure of money in engineering work, has, I believe, resulted in the preceding regulation. For many years something like the new Act appeared several times before Parliament—but at all times disappeared either by being abandoned outright by the promoters, or failed from some political or similar cause. The new Act, which I believe must benefit our country, was largely made possible by a contribution from imperial sources towards local taxation. This contribution, I think, is about three-quarters of a million pounds sterling a year. English ratepayers were in receipt of a contribution to aid local taxation before our new Act, which fact, no doubt, made it possible for like treatment for Irish ratepayers.

The Local Government Act of 1898 must, both directly and indirectly, open up a new and, I believe, a better era for Ireland. The old Bodies now replaced by Councils did good work in their day; but, owing to their constitution and range of powers, they became fossilized and behind the times. Their principle necessarily was to let well alone and avoid the risk of change. Although unsuited to the high-class machinery required in the present day, I think history will say of them, on the whole, that they aimed at economy, and did their duty honestly and conscientiously according to their powers and light.

Under the new Act every man is equal as regards voting power and eligibility for office, and the fact of owning or occupying or managing large tracts of the land of the country no longer confers so many votes per so many acres of soil. So, too, Justices of the Peace have now no *ex officio* voice in the expenditure of public money, nor can they, without election, sit at a Council Board. As the

result of the first elections by ballot we find that many members of the old Boards have been returned on the new ones. Looking to the future, I believe such members (*ex officio* or otherwise) and their class have just as good a chance of being elected Councillors as any one else. But this cannot be unless they take an active and sympathetic part in what concerns their districts and the welfare of their neighbours, and this will be done in the future, I think, gradually more and more. Have we not here a promise that the old barriers which, actively or passively, made against community of interests will gradually be razed, and that all classes of Irishmen will, as time goes on, acquire the habit of seeing farther than their own demesnes, farms, half-acre plots, or lodging house doors, as the case may be? Union will produce strength after a time capable of efficiently dealing with grievances, whether due to legislation or want of legislation in the past, and it must result in advance generally. That Ireland has grievances no one will deny, and I am sure it will be the aim of the new Councils to get same remedied, quite as much as to work within the four corners of the Act itself. No Government can turn a deaf ear for long to the united and righteous demands of our new public Bodies. I am not speaking of any political or such like grievances, but of those which stand in the way of industrial enterprise and the free development of the economic energies of Ireland—it would be easy to name several of these. The ultimate cause of some grievances may be natural ones impossible to remove, or even to alleviate, but there is one great artificial grievance which has burdened this country since the Union that could be, if properly set about, removed by a stroke of the pen. You will anticipate that I refer to the Private Bill system in Ireland during the last century. Can any one doubt that, had a local tribunal been created when the two Parliaments

were united, our progress would now be far greater than it is? And the burden of the system has been getting greater and greater every year according to increases in discoveries and inventions. Nothing should stand in the way of having inquiries of a local character and entirely Irish conducted in Ireland. Of course the question of a tribunal will crop up, but it is really too trivial for busy and unprejudiced persons to consider seriously; it is more, it is contemptible.

To us Engineers, whose brethren have changed the face of the world since the beginning of the 19th century, it seems not to require large mental calibre to find a tribunal to sit here in Dublin for Irish business after the experience of a century. Anyhow, I believe the new Councils will try and have the question solved. And they will find ready at hand many other problems wanting solution. For really we may say, without seeking to attach blame to anyone, that compared to other places Ireland is practically as Nature made it, dependent on the grass that grows, and that not as good as it could. It does not require one to be a specialist to know that our agricultural methods are behind the times. What, however, chiefly strikes an engineer on this point is want of river and arterial drainage and want of trees. Rivers, large and small, flooding miles and miles is a common sight, while treeless wastes cover a large proportion of our acreage.

Then as regards industries, properly so called, we have seriously to ask is there any fiat of Nature against them? I do not believe, artificial obstacles being removed, that there is, unless we take up the unreasonable ground that because we cannot compete against all comers in everything we should not try anything. It will be said, perhaps, that private enterprise should fully develop a country if the country is worth developing. That not so very long ago could

also be a homily against the present system of postage and telegrams. Mentioning the Post and Telegraph Departments means that we should have a Railway Government Department for cheap delivery of goods, raw and otherwise—and this also applies to canals. Two of our past Presidents in their addresses spoke of the necessity for cheap internal communication from place to place in Ireland and to the sea-board, and I believe their suggestions on the subject have now a better chance of being realised than at any time in the past. With railways and canals nationalised (same as the Post Office) there should be—I cannot say a revival, but new and expeditious roads opened for industries amongst us, including, of course, a new era for agriculture.

Probably this address is already too long, so I will conclude by saying that here in Ireland industries, if properly set about, should be possible and profitable. We have water power, metalliferous ores, building stones, roofing slates, brick clay, &c., to say nothing of our capacity for timber and other vegetable products used in manufactures. Lastly, though perhaps not least, we have a supply of peat, which only awaits developments in science to one day be of great value—and even at present its proper working should pay in many ways.

To-night we stand almost upon the dividing ridge of two centuries. We look back with pride to what engineers have done during that now coming to a close. Let us hope that the coming century will be equally indebted to our profession, and that Ireland will be one of the countries to have cause for gratitude.

APPENDIX (I.).

County.	Average Yearly Expenditure on Roads during the 3 years before the passing of the L. G. Act, 1898.			Limit of Expenditure per annum under L. G. Act.		
	£	s.	d.	£	s.	d.
Antrim	60,203	0	0	75,253	15	0
Armagh	27,748	0	0	34,685	0	0
Carlow	9.942	0	0	12,427	10	0
Cavan	13,591	0	0	16,988	15	0
Clare	23,464	0	0	29,330	0	0
Cork	70,519	0	0	88,148	15	0
Donegal	28.900	0	0	36,125	0	0
Down	50,050	0	0	62,562	10	0
Dublin	39,382	0	0	49,227	10	0
Fermanagh ...	15,135	0	0	18,918	15	0
Galway	25,183	0	0	31,478	15	0
Kerry	21,922	0	0	27,402	10	0
Kildare	17,727	0	0	22,158	15	0
Kilkenny ...	23,934	0	0	29,917	10	0
King's County ...	13,119	0	0	16,398	15	0
Leitrim	9,556	0	0	11,945	0	0
Limerick ...	32,480	0	0	40,600	0	0
Londonderry ...	23,955	0	0	29,943	15	0
Longford ...	6,517	0	0	8,146	5	0
Louth	12,417	0	0	15,521	5	0
Mayo	20,067	0	0	25,083	15	0
Meath	19,354	0	0	24,192	10	0
Monaghan ...	13,449	0	0	16,811	5	0
Queen's County ...	15,611	0	0	19,513	15	0
Roscommon ...	16,381	0	0	20,476	5	0
Sligo	13,286	0	0	16,607	10	0
Tipperary, N. R. ...	20,054	0	0	25,067	10	0
Tipperary, S. R. ...	22,397	0	0	27,996	5	0
Tyrone	44,607	0	0	55,758	15	0
Waterford ...	16,634	0	0	20,792	10	0
Westmeath ...	13,153	0	0	16,441	5	0
Wexford	20,075	0	0	25,093	15	0
Wicklow ...	14,400	0	0	18,000	0	0
Total for Ireland ...	775,212	0	0	969,015	0	0

FORM 14.—RECOMMENDATIONS AS TO PROPOSALS FOR PAYMENTS ADDED BY COUNTY SURVEYOR TO HIS REPORT

Under the provisions of Article 8 of the Local Government (Procedure of Councils) Order, 1899.

County of _____

District of _____

Quarter ended the _____ *day of* _____ *18* ____

SCHEDULE of Applications for Payments in respect of Public Works in the District, to be considered at the Quarterly Meeting of the District Council, to be held on the day of 18 ; with the recommendations of the County Surveyor, setting forth the Proposals for Payment and other decisions which he considers should be made in each case by the District Council at the said Meeting.

No on District Register.	Date of Quarterly Meeting when Proposal was originally made.	Matter in relation to which the application for Payment is made.	Whether wholly or partly a County Charge or a District Charge	CONTRACTORS.		a Amount Payable under the Contract to the end of the Quarter.	a RECOMMENDATION OF COUNTY SURVEYOR.			Initials of County Surveyor	Decision of District Council.
				Name.	Postal Address.		To Pay.	To Defer	To Strike off.		
1.	2.	3.	4.	5.	6	7.	8.	9.	10	11.	12.
						£ s. d.	£ s. d.	£ s. d.	£ s d.		

a If more than one Quarterly instalment remains unpaid on foot of a continuing contract, the particulars and recommendation with regard to each should be set out separately in this Schedule.

CERTIFICATE OF COUNTY SURVEYOR.

I hereby Certify that the several Works in respect of which Payments are by me recommended to be made as per Column 8 of the above Schedule have been executed in accordance with the respective Contracts, and that in the several cases where payments are recommended to be made before the completion of the respective Contracts, such payments may be so made under the terms of the said Contracts.

Dated this _____ day of _____ 190____ _____ *County Surveyor.*

APPENDIX (III.)

LOCAL GOVERNMENT BOARD FOR IRELAND.

APPOINTMENT OF ASSISTANT SURVEYORS FOR COUNTIES IN IRELAND.

WHEREAS by Sub-section (4) of Section 83 of the Local Government (Ireland) Act, 1898, it is provided in effect that no Assistant Surveyor shall be appointed or removed without the concurrence of the Local Government Board for Ireland, and that every such Assistant Surveyor shall have such qualifications (if any) as that Board may prescribe:

NOW THEREFORE We, the said Local Government Board for Ireland, do hereby prescribe with respect to the appointment of Assistant Surveyors for Counties in Ireland, as follows, that is to say:—

1. Every person who is appointed an Assistant Surveyor in any County in Ireland must produce satisfactory evidence to the Local Government Board for Ireland that his health and character are good, and, except in the case of an existing Assistant Surveyor within the meaning of Section 109 (1) of the Local Government (Ireland) Act, 1898, that at the date of the resolution of the County Council appointing him his age was not less than 21 years, or more than 45 years.

2. Every person appointed as aforesaid who

(*a*) has a diploma or degree in Engineering from a University or College of Science in the United Kingdom, or a certificate from Her Majesty's Civil Service Commissioners, that he is qualified to act as a deputy for a County Surveyor; or

(*b*) is an Associate Member of the Institution of Civil Engineers, London, or an Associate Member of the Institution of Civil Engineers, Ireland, or has a certificate of having passed the Voluntary Examination for candidates for Surveyorships held by the Incorporated Association of Municipal and County Engineers;

(*c*) was on the first day of April, 1899, an Assistant Surveyor in a county in Ireland, or if appointed in any such county between the first day of April, 1899, and the date of this Order, satisfies the Local Government Board for Ireland that he is fully qualified to discharge the duties of his office,

shall be deemed qualified for the position of Assistant County Surveyor without further examination.

3. Every person appointed as aforesaid who is not qualified under the provisions of the foregoing Article of this Order must produce to the Local Government Board for Ireland satisfactory evidence that he has profited by training in one of the two following ways, that is to say, either

(1) By service with a County Surveyor, Civil Engineer, or Architect for not less than two years; or

(2) By attendance at an Engineering School of some University or College of Science in the United Kingdom for not less than one year, and by having been engaged in practical work in connection with Civil Engineering or Building for one year at the least.

4. Every person appointed as aforesaid who is not qualified under the provisions of Article 2 of this Order must, in addition to possessing one of the qualifications specified in Article 3, also pass a qualifying examination to the satisfaction of the Local Government Board for Ireland in the following subjects:—

(1). English Composition as tested by writing a business letter from rough notes, or a short essay on some subject connected with his profession.

(2). Arithmetic.

(3). Mensuration.

(4). Building construction.

(5). Construction and maintenance of roads.

(6). Chain surveying and levelling.

5. The provisions of the foregoing Articles shall be and remain in force until we otherwise order.

[9th January, 1901.]

MR. EDWARD GLOVER, President, in the Chair.

The following Candidates were balloted for and duly elected, viz.:—

MR. ALINSIO LEONARD COLACO, as Associate Member, and Messrs. C. W. GORDON and JOSEPH TATLOW, as Associates.

THE CONSTRUCTIVE POWER OF THE SEA.

By R. G. ALLANSON-WINN.

IF a small stone or other heavy solid body be placed upon a smooth sandy shore when the tide is coming in, and the waves are moderate in their force, it will be found that a distinct scour takes place in the neighbourhood of the stone which the retreating tide leaves somewhat sunken or buried, and with a small pool of water on one side or possibly all round it. If the wind is high, and the waves heavy, the stone will probably be rolled in-shore, and take its place along with the other pebbles forming the beach.

If a similar small obstruction be placed in a favourable position on dry land, where the sand is blowing in large quantities, the reverse of a scour will often be observed, a small mound forming round the obstruction.

In the first place, the water acting through its weight and motion on the particles of sand around and beneath the stone causes the scour, and in the latter case the lighter action of the wind carries the heavier particles of sand until they are deposited and arranged around the obstruction, generally in a small cone-like mound—the arrangement of the particles and shape of the mound being infinitely varied according to the conditions and circumstances.

A consideration of these simple phenomena is full of interest, for we are contemplating what may be termed initial scours and silts.

An examination into the origin of many vast accumulations of material, whether that material has been collected by the action of water or wind, or by the combined action of the two, reveals the fact that the direct cause of initial deposit is often some extremely small and insignificant obstruction.

A walk along the coast-line among the sand dunes on a day when there is a slight breeze blowing gives the opportunity of observing many small blades of bent grass, pieces of stick, &c., round which the drifting sand is collecting. Any one of these small cone-like mounds may in process of time grow into a sand-hill, perhaps 80 or 90 feet high, and containing thousands of tons of sand. This great mass of material may be grassed over and held together by the long bamboo-like roots of the bent, and may for a considerable period afford burrowing accommodation for countless generations of rabbits. Then, at last, the day comes when the sea encroaches; the big sandhill is undermined, and, gradually slipping down, offers its denuded side to the on-shore winds, which carry away the particles in clouds to be deposited elsewhere—generally further inland—and the whole process is repeated over again. The birth and the death of the big mound have taken place, the length of its life having been controlled by circumstances and agencies which we are aware of, but the intensity of which we have no means of gauging.

Again, we take the case of a stream far away in the upper ranges of the Himalayas. A small tree or other obstruction falls across the stream in such a manner as to collect twigs, and, later on, sand and stones, during the winter months. A hot summer's day melts the snow on

the distant mountain tops, and the stream is converted into a roaring torrent, which, being diverted at the point where the collection of chance material has formed a barrier, cuts a fresh channel for itself, and perhaps alters the physical aspect of a whole country side—the most prominent result probably being the starting of lands-slips and consequent carrying away of roads and bridges, or the burying of native villages.

Many of the mighty Indian rivers have a way of altering their courses from time to time, and causing great loss to the Zamindars or cultivators of the soil. Where they do not actually work out fresh channels they very frequently bulge in on the banks and overflow hundreds of acres of land. On the Ganges and its tributaries it is a common practice, when it is desired to reclaim land thus inundated and force the river back into its original channel, to run out long, slender groynes, composed of bamboo stakes and wicker work interlacing. These groynes, which are at right angles to the stream, terminate in a T-shaped structure, of similar construction to the groyne itself, at the point where it is considered the banks of the river should commence.

When a sufficient quantity of alluvial deposit has been collected, the T-shaped ends are joined together with wicker work, which then forms a new line of artificial bank, and the apparently insignificant obstructions have gradually but surely effected their purpose.

For many years the navigation of the Mississippi was seriously impeded by shallow bars at the estuary and by general want of depth of water. On the suggestion of Captain Eads, an expert who had for years considered the question, groynes, or, as they were there called, "matrasses," were run out, with the result that they slowed down the currents, and encouraged deposit to such an ex-

tent that the main body of water, gradually forced into its proper channel scoured out the bed of the river, and increased the depth from ten to thirty feet. Here, again, as in the Ganges, the small obstructions did their work of "trapping" or accumulating.

It was, however, reserved for an English engineer, the late Mr. Edward Case, to apply the principle of low groyning for purposes of sea-coast protection. Mr. Case took a long step in advance when he promulgated his theory that every shore had its own inclined surface of repose, and that that surface could be brought about by accumulations mainly derived from the travelling material between mean sea level and low water mark.

If, he argued, a shore can be made to once acquire this surface *from which there is the minimum chance of alteration through the action of waves and currents*, sea walls, properly so-called, will not be so necessary as formerly for the protection of esplanades, sea-side roads, &c. If a good "full" of beach can be secured a comparatively light retaining wall will be sufficient, and we shall be able to rely on the beach itself as a protection for our foundations, whilst we shall have the satisfaction of having saved heavy expense in costly concrete blocks, &c., which would otherwise have been considered necessary.

Experience and close observation convinced Mr. Case that there was an extensive travel of shore material between mean sea level and low water mark, and experiments proved that by the use of long, low groynes the material-bearing lower currents could be directed shorewards until sufficient deposit had taken place, and the desired surface of repose was acquired. He sought to build up the shore from its lowest point—*i.e.*, low water mark—and in doing this he was but following the usual custom, for a shore is, after all, but an embankment with

a very flat gradient, and, as we know, every embankment must be started from its foundation or lowest point.

Being thoroughly convinced of the soundness of his theory, Mr. Case set to work to design a form of low groyne which should be at once simple, inexpensive, and capable of rapid construction, and after making several experiments hit upon a design and method of construction which may be shortly described here:—Holes are dug in the shore in line of the proposed groyne, and uprights or piles are placed vertically in them, usually 7 ft. 6 in. apart from centre to centre, the depth of the holes and length of pile varying according to the nature of the foundations. The uprights, which consist of pairs of 7 in. by 2½ in. battens bolted together, with distance pieces at the top, and sole, or key pieces about 18 inches long at the bottom, having been placed in position, the holes are filled in with slightly damped concrete, tipped in and well trodden down This mass of concrete, when set, holds the upright firmly in position. The planking, which is also 7 in. by 2½ in., previously cut into 7 ft. 6 in. lengths, is next inserted horizontally between the pairs of uprights and temporarily, but securely, held in position by a 6 in. spike, which is easily drawn when it is necessary to add or remove planks. A narrow trench is cut between the uprights to insert the first two or three planks below the level of the shore, this being necessary to prevent a flow of water beneath the lowest plank. The groynes are so stepped that they shall follow the calculated inclination of the shore. As the sand or beach (and it may be here noted that the groynes act equally well with sand or shingle) accumulates, fresh planks are added, and when the groynes are buried, if it is necessary to still further raise the level of the shore, similar uprights are bolted to the planks, and the process of inserting the horizontals

is continued as before. In this case, as the original groyne is buried, and therefore secure, no additional concrete is required, the new set of uprights being securely held to the buried groyne by the bolts.

There are four advantages which are specially claimed for these groynes:—

1. The economy effected in time, labour, and cost of materials.
2. No plant or skilled labour are required, although care and experience are necessary for the correct adjustment of the planking.
3. All the timber used is of the same scantling.
4. The cost of maintenance and repairs is very trifling.

In putting down these groynes it is usual to commence at or about mean sea-level—a point where the ordinary high groynes leave off—and then to run them down to low water mark at right angles to the low water line. The rapidity of action depends, of course, on the quantity of material afforded by the neighbourhood and to a great extent on the winds and tides.

Taking a broad and comprehensive view of the discovery we observe that the principle of small obstructions and the multiplication of small results gradually bring about the change sought—there is nothing sudden; no abrupt interference with existing forces. The deposits are made gradually, and *at the proper place for the correct building up of the long smooth bank which is destined to protect the shore at high water mark.* We also notice that the services of that restless, never-tiring workman, the sea, are enlisted, and that the winds and waves help to stir up and carry particles which are caught by the low groynes and directed shorewards. In fact, it may be said that the destructive forces of the elements are converted into constructive forces. The small and gradually accumulating

silts are encouraged at low water mark, and further encouraged until the shore is added to and "built up" as it were.

The correct form of any shore composed of beach or any other shiftable material is a gradually sloping surface, the section of such shore between high and low water marks being an ellipse, the construction of which depends upon the range of tide and the horizontal distance between high and low water marks

Very few natural shores lie at this desirable inclination; the section of a shore between high and low water marks is seldom a true ellipse, but the nearer the sections on any shores approximate to true ellipses the less damage is done by the sea along that particular portion of the foreshore. In some instances, the curve being nearly perfect and free from any abrupt angles or changes throughout its entire length, the waves roll harmlessly in at the flood tide, and equally harmlessly retreat with the ebb. Fig. 1.

Take the case of a railway truck running down an incline of rails and gaining sufficient momentum to run up another incline. If the rise is quite gradual, and there are no angles or obstacles of any kind, no damage will be done; the truck will run up till stopped by the ever-acting force of gravity, and will then run back again without doing any harm. But if you place any obstacle on the line, or there is any break in the continuity—any abrupt angle, as it were—something has to go, something is injured or broken.

If we examine any shore at random, we shall probably find a well-defined angle, somewhere about mean sea level, where the beach leaves off and the sand begins, the beach angle being the steeper from a point above high water mark to the junction with the sand, and the sand from this point lying at a much flatter inclination right down to low

water mark. The characteristics of no two shores are exactly alike. We may hit off a couple of places where the range of tide, nature of shore material, prevailing wind, &c., are all practically the same, but closer examination will reveal some factor which they have not in common—some sunken bank far out at sea or some particular ocean current.

It may be conceded that, roughly speaking, there are six types of coast-line:—

1. The rock-bound coast, where erosion goes on so slowly as to be practicably imperceptible—*e.g.*, Cornwall, Aberdeen, North of Ireland.

2. The line where denudation of beach and other shore material is a serious menace to sea walls, esplanades, and cliffs, composed of more or less easily eroded material—*e.g.*, Brighton, Hastings, Folkstone, Ventnor, Shanklin, Sandown, the Holderness coast of Yorkshire, and generally the sites of watering places all round the coast.

3. Where masses of shingle are being driven inland.

4. Where the shingle has disappeared and there is no full of beach to arrest the encroachment, and

5. Where shores are so cut about that they consist of bare rocks, pools of water, wet sand and mud, and are therefore most unsuited for recreation grounds for children and others—*e.g.*, Worthing and Herne Bay.

6. Where extensive scours have been caused on the lee sides of high groynes, as at Hastings, St. Leonard's, and Brighton.

As is almost invariably the case with any new contrivance or method, the low groynes were at first looked down upon with contempt, partly on account of their slight nature and cheapness, but more especially because of their novelty. There were also many people who argued that the groynes might answer well enough on a sandy shore

like Dymchurch, but that they would be of no use in places where shingle predominated, or where shingle and sand together were to be dealt with. To prove how incorrect these arguments were, we have only to point to Southwold, where there is only shingle, and Deal, where both shingle and sand are to be found. The author believes that the principle is correct for any shore whatever, with any range of tide, save, alone, a rock-bound coast.

"At Dymchurch, which must be regarded as the cradle and home of the Case system, the problem was one of extreme difficulty, and it was not until many experiments had been made that the groynes were applied with success. On consulting the section it will be observed that in 1894 low water mark was near the toe of the wall, and that a dangerous swill existed close up to the sheet piling. In June, 1897, between six and seven feet of sand had accumulated about 200 feet from the wall, the swill and bar were completely obliterated, and the sheet piling was buried some three feet beneath the sand. In April, 1898, this improvement was continued, the last section taken being indicated by the thickest line. This inclination is maintained, however heavy the wind or sea, and the wall is to all intents and purposes safe. Deep water no longer approaches the sheet piling, the paving is protected, and the sea, no longer abruptly checked at any portion of its course, from low to high water, has ceased to do any serious damage. Fig. 2.

"It is a remarkable fact that not one of the piles in all the 120 groynes at Dymchurch is set in a solid foundation. The shore was formerly a succession of bars and swills and soft mud and sand, and the result of setting the piles and constructing the groynes over this treacherous ground is the fine stretch of sand alluded to by Mr. Grantham in his paper of November 1st, 1897. The

Dymchurch groynes, if placed end to end in a line, would extend to a distance of 10 miles; they vary from over 300 feet to over 1,000 feet in length. How many fashionable seaside resorts would be improved by the acquisition of such sands! The Dymchurch sands are not a little envied by places like Worthing and Herne Bay, where the system has not been properly applied and extended, or else has not been tried at all." Fig. 3.

The above is quoted from a paper entitled "Foreshore Protection," which gained the Bessemer Premium of the Society of Engineers in June, 1899. It by no means exaggerates the difficulties which existed at Dymchurch, and, if the aphorism about the best sailors being trained in the most boisterous seas can be applied to foreshore engineers, Mr. Case had indeed a good chance presented to him. A volume might be written full of interesting matter connected with the inception of the work.

The nature of the Dymchurch shore was such as to render the erection of inexpensive groynes extremely difficult.

Mr. Case commenced operations with a few experimental low groynes put down between low water mark and mean sea level, and normal to the curve of the low water line. The results of these experiments were so far satisfactory that he was able to practically demonstrate three important facts, viz:—

1. That material travelling laterally along the coast-line, near low water mark could be arrested and diverted inland towards those portions of the shore which required raising; and,

2. That the low, slender structures which he put in created no scour; and,

3. That, from the fact that they presented but little surface to the forces of currents and waves, they were not liable to be torn out or damaged even by the severest storms.

In September, 1899, Mr. Case prepared a paper entitled "The Dymchurch Wall, and Reclamation of Romney Marsh," which was read to the British Association meeting at Dover. In referring to the work he had undertaken with low groynes for the protection of the great sea wall and the marsh lands, Mr. Case thus expressed himself:—

"Since 1894 the groynes have been extended from time to time as the low water mark receded, and as the original work was buried by accumulation of the material the groynes were raised in some instances as many as three times. Groynes have now been placed westward as far as Dymchurch. Between Willop and Dymchurch they are spaced from 150 to 200 feet apart, and are from 700 to 1,000 feet long. As the opportunity arises they are extended seaward. Fig. 4.

"Since 1894 a length of about 10 miles of low groynes has been put in. The work is still in progress, and will, no doubt, be so for the next few years. The effect of the groynes has been to raise the level of the foreshore as much as 8 feet at the east end of the wall. The average depth of sand and shingle collected between the Grand Redoubt and Dymchurch is 4 feet 6 inches, and amounts to about 1,500,000 tons. Fig. 5.

"Between the Grand Redoubt and Willop the foreshore has been built up to its natural inclination of repose, which the author has found, by constantly taking sections during the past two winters, is never disturbed by gales from any quarter, and he believes for the past 200 years the marsh has never been so secure from inundation as it is at the present time. The character of the foreshore has also changed. When the work was commenced it consisted of running sand and mud, but now it is a well-consolidated mixture of beach and sand.

"Of course, there is always the risk of damage taking

place when any artificial work is exposed to heavy seas, but now the area so exposed at Dymchurch has been reduced by more than one-half. In some places the foot of the paving has been covered with sand as much as 50 feet in width.

"This has minimised the risk of damage to the upper part of the wall, which is the only portion now exposed.

"Until the barrier of beach and sand which formerly existed shall have been restored the author's work will not be complete.

"This is only a question of time, if the work commenced in 1894, and still in progress, be persevered with.

"A foreshore which took many years to waste away cannot be built up again in 4 or 5 years. The foundation of the structure has been laid, and the process of building upon it is progressing as rapidly as can be expected.

"The author is convinced that it is useless to erect groynes near high water mark for the purpose of trapping beach. Under favourable conditions the beach will accumulate, and will continue to do so for some years, but almost invariably only on the windward side of the groyne. One gale dead on shore with a very high tide will sweep it all away. Unless a foreshore be built up to its true elliptical inclination, there can be no stability. Every wall exposed to the action of the sea has its lifetime, and is never safe unless protected by the natural barrier of sand and shingle, which a properly graded foreshore provides.

"It is the business of the engineer to utilise the forces of nature, and not to oppose them. The sea has a constructive as well as a destructive power, and can be made to build up its own defence of beach and sand. The under currents which run along shore in the direction of wind and tide should be diverted and gently guided towards

the shore. By this means a hard and perfect slope will form, up and down which the waves can harmlessly roll, and gradually expend their force before reaching high water mark.

"Such results have been achieved at Dymchurch and at other places where the author's method of building up a foreshore is in progress.

"To those interested in sea defence Dymchurch is well worth visiting. It is a practical illustration of how great results can be produced by the proper application of simple means."

Such was the opinion of the late Mr. Edward Case, whose untimely death was a severe blow to the science of foreshore protection, and was regretted by those engineers who, interested in this particular branch of the profession, regard his system as based upon correct principles, and far more effective than the ordinary system of high groynes.

From the foregoing remarks it will be gathered that the Case system of foreshore protection aims at encouraging gradual deposit of material until the shore has made up so as to show the best possible section through any portion of its surface.

If we turn for a moment to a consideration of the actual results produced by the high groynes, which engineers have for years past adopted all round these coasts, we shall find that, in 99 cases out of 100, scours are caused at the very points it is necessary to protect. The Hastings and St. Leonard's foreshore furnishes an excellent example. It is typical of the high groyne system. The photographs show the deep scours on the lee sides of all the groynes, and the shore has all the appearance of a large saw when viewed from the sea. Each groyne is a distinct source of weakness to the wall as a whole. The scours to the lee

are turned into small deep fjords at high tide, and into these the sea rushes with terrific force whenever there is a storm dead on shore or from the S.E. Fig. 6.

During such a storm the wall will be attacked at its lowest foundations. Fig. 7.

On the Hastings shore we also observe that there is a marked scour all along the sea ends of the high groynes, the soft yellow sandstone being exposed and constantly subject to erosion through the sawing action of flint shingle which is carried laterally along the shore with every tide In the course of time this encroachment must reach the line of the esplanade wall many feet below its present foundations, and the expense of underpinning, toe walls, sheet piling, &c., will be very heavy. The serious objections to the ordinary high groynes may be summed up as follow:—

1. Scour close up to wall. Fig. 8.

2. Scour at, or about, mean sea level and general denudation of the shore between mean sea level and low water mark.

3. Danger to children.

4. Impossibility of getting along the beach without the exercise of more than ordinary agility in climbing up or down vertical structures of 8 or 10 feet in height.

It is not going too far to say that one or more of these objections apply to nearly every shore in the British Isles where high groynes have been used.

An examination into the causes of breaches in sea walls has convinced the author that the mischief is very frequently traceable to the existence of some high groyne in the vicinity of the breach.

Corporations continue to vote large sums of money for the erection of costly high groynes of an obsolete pattern, each of which is in itself a distinct menace, and, regardless of the object lessons with which they are surrounded, really

add to the cost of maintaining their walls without bringing about any permanent improvement in their foreshores.

In a communication made to the Society of Engineers, London, in June, 1899, Mr. A. Dowson said:—"I cannot but congratulate Mr. Case on the success he has obtained; and as Brighton is probably the shore which can show the largest number of hideous solid groynes, I trust Mr. Case may succeed in having sufficient influence to bring about their total destruction."

Of course this is rather strong language and not likely to meet with the approval of the Brighton authorities, who have expended and are expending such large sums of money on their unsightly groynes. What Mr. Dowson really wished to convey was that the Brighton shore would be more attractive and more safe if the high groynes had never been constructed. The authorities at most seaside places are quite contented to go on spending money in the happy belief that what was good enough for their predecessors is good enough for them. They have a particular aversion to anything new, and the saving of cost and scientific nature of a discovery seem in themselves to be elements or factors to be regarded with suspicion and disfavour.

It was a very long time before Captain Eads could get anything like a hearing when he advanced his scheme, alluded to in the commencement of this paper, for deepening the Mississippi estuary, and yet the scheme itself was simple and inexpensive, highly scientific, and, as results showed, eminently practical.

The author has now under his observation several sea walls where the approach of low water mark to the foundations has necessitated the addition of toe walls from time to time, and he can produce abundant evidence to show the damage done by high groynes, in such cases, not only

near the wall but at mean sea level, where probably the worst erosion takes place.

It would be easy enough to multiply examples of the damage done by high groynes, and the author will be pleased to furnish actual details with respect to numerous shores, both in England and Ireland, which have been under his close observation for many years past.

We will now turn to a consideration of the Deal foreshore, where there are no high groynes. In 1898 the esplanade wall between the town and Sandown Castle was in considerable danger, for the beach, all along that distance, had been scoured out during the summer months. This, it may be remarked, was a quite unusual occurrence; the experience of past years pointing to denudation during the winter and accumulation during the summer months. This being so, and the authorities having no hope of collecting material in the winter of 1898-9, there was considerable cause for alarm. The shore was so far denuded that the foundations of the wall were exposed, and the owners of property between the golf links and coast guard station not unnaturally feared that the wall would be breached.

Early in the autumn it was decided to try the Case groynes, and the work, which was in charge of Mr. John Monckton Case, was pushed on as rapidly as possible. Between September, 1898, and February, 1899—*i.e.*, during the five worst months of the year—a very great change for the better was manifested. The "full" of beach had increased so as to effectually protect the toe of the wall, and, what was more important as affecting the future stability of the work, the form of the shore had vastly improved, an accretion of four feet having taken place at the worst point below mean sea level, and low water mark having been driven back over 200 feet. In these few months the sea, through the agency of the Case groynes, had accumulated

over 3,748 tons of shore material, both beach and sand, per 100 feet of coast line. This beach now lies evenly against the wall; there is no indication of any scour, and there are no unsightly high groynes to interfere with the enjoyment of a walk. This protection work has now stood the test of many severe storms, and visitors to Deal who remember the former state of affairs will not fail to be impressed with what they see now. Figs. 9 & 10 (Deal).

The photographs and sections which illustrate this paper show, more clearly than any mere description can possibly do, the remarkable and satisfactory results which have been brought about.

At Southwold, on the east coast, a steep shingle beach had to be dealt with. There exists a deep swill just outside low water mark, and the shore is a very exposed one. When Mr. Case took this shore in hand early in 1898, the waves were constantly breaking down the sheet piling and low concrete wall which had been erected for the protection of the rapidly disappearing cliffs. High water mark was within 41 feet of the cliff face, and people were deserting their houses in the full belief that they were no longer safe.

It is instructive to note the gradual and steady improvement which has taken place on this shore since the Case groynes were put down, and the following table concisely shows the recession of high and low water marks, and the accumulation of beach in tons per 100 feet of coast-line.

Recession of the Sea.			Accumulation.		
			H.W.M.	L.W.M.	per 100 feet on the Coast line
April, 1898,	to	Sept., 1898,	20 feet	6 feet	832 tons
,, ,,		Oct., ,,	28 ,,	15 ,,	1,412 ,,
,, ,,		Dec., ,,	40 ,,	36 ,,	2,424 ,,
,, ,,		Jan., 1899,	48 ,,	49 ,,	3,187 ,,
,, ,,		Sept., ,,	68 ,,	54 ,,	3,787 ,,

So that it will be seen that this large accumulation of 3,787 tons of material was gathered in ton by ton as it were, and that the pushing back of high water and low water has been accomplished step by step over a period of 18 months. During the past year the improvement has been maintained, and the groynes have been raised three times—the land ends of the original groynes having long since disappeared beneath the ever increasing new shingle bank, which, it will be observed, is between 6 and 7 feet at its deepest point. The waves of the highest tides no longer reach the toe of the cliffs, and the residents begin to hope that their homes may, after all, escape destruction.

The photographs and sections give a very clear idea of the condition of the shore before and after the adoption of the system.

Another very interesting example of successful work is to be found at Mundesley, on the Norfolk coast. Here Messrs. Case and Gray designed a sea wall, stepped in such a way as to accommodate itself particularly well to the action of the Case groynes. As will be seen by reference to the section and photograph, the major axis of the ellipse terminates in the wall just below the promenade. The wall itself is a comparatively slight structure, but quite strong enough to throw back any surface water, which, in exceptionally high tides, may be dashed against it in the form of surf. Here, again, attention is particularly invited to the manner in which the whole shore has improved in section. In October, 1898, high water mark was practically up to the toe of the existing wall; in six months' time it had been driven back nearly 40 feet, and in that same time low water mark had receded 64 feet. Nearly all the steps of the wall are covered, and there is an accumulation averaging 2 feet deep for a distance of nearly 100 feet. Lower down again, at a distance of 300 feet from the wall, the

sand accumulation is three feet deep, and at 361 feet, which was the distance of old low water mark, there is now a deposit of firm sand over 2 feet 6 inches above the present low water mark 64 feet further on. The accumulation from October, 1898, to April, 1899, has been calculated at 2,846 tons per 100 feet of coast-line.

Figs. 11, 12 and 13 show how the action of the Case groynes obliterated an extensive swill on the sandy shore of Cromer.

At Sheringham and Beeston, also on the Norfolk coast, instructive examples are to be found, for here we have evidence of the treatment of three foreshores, lying side by side, two of them having been successfully treated by the Case system, whilst the third is at present in a neglected and unsatisfactory condition. The foreshore to the west is the property of a private gentleman (Mr. Upcher), then comes the town foreshore in the middle, and then the Beeston foreshore to the east. Mr. Upcher's and the Beeston shores have been and are protected by accumulations brought up by the Case groynes, but the town foreshore is unprotected, and the sea is continually encroaching all along the new sea wall.

In July of the present year there was a depth of 6 feet of water at ordinary spring tides opposite the Crown Hotel. Careful observations and measurements show that in a period of ten months Mr. Upcher's foreshore had accumulated 1,050 tons per 100 feet of frontage, and that of Beeston had in the same time over the same frontage gained to the extent of 1,149 tons. All this time the unprotected portion had gone on wasting away at the rate of about 380 tons per 100 feet of frontage. It is also shown that high water mark has been driven back at Mr. Upcher's, and at the Beeston shores, and has as steadily gained on the land opposite the town.

It may be mentioned that all these works and very many others have been carried out by the Case Sea Defence Syndicate, Ltd., the contractors who are the licencees of the patent rights of the late Mr. Edward Case, the discoverer of the system, and that Messrs. Case and Gray are the consulting engineers.

Amongst the numerous problems with which foreshore engineers are confronted is that which relates to the alteration of currents, and their effect on the coast-line. A shore will, for example, maintain for years a uniform curve, the shingle bank perhaps gaining in one set of tides and winds and losing in another set, the sand possibly scouring away in winter and accumulating in summer. Then there comes a certain year in which there is a very marked encroachment of the sea, the next year follows with fresh erosion, and so on with each succeeding year, until owners and residents, forced to the conclusion that their land is being steadily filched away from them, look around in despair for some means of staying Father Neptune's ravages. In this connection, and quite parenthetically, it may be observed that it is usually at the eleventh hour when advice is sought.

The author is of opinion that this form of encroachment may be usually traced to the formation of submerged or partly submerged banks, not necessarily in close proximity to the shore undergoing erosion, and that these banks cause a change in the direction of ocean currents during the flow and ebb of the tide. Fig. 14.

In 1897 he was called in to advise the trustees of the Glenbeigh estate in County Kerry as to the best means to adopt in dealing with the very rapid encroachment of the sea on the southern shore of Dingle Bay, at a point where a road and houses were in immediate danger. The author's experience of this foreshore goes back over 30 years, and,

though he cannot remember the time when there was no perceptible advance of high water mark, it is only within the past 15 years or so that the encroachment seems to have become more marked. Contemporaneously with this cutting away of the shore, a vast sand bank, only visible at either. It seems highly probable that much of this sand-low water, had been steadily forming between the northern and southern shores, at a distance of about 3 miles from bank is composed of material eroded from the Glenbeigh foreshore, and that it causes the currents to impinge with ever-increasing force upon that foreshore.

On consulting the plan it will be seen that at one point the edge of the cliff is within 10 or 15 feet of the road, and that the houses are built close on the road.

The idea of building a wall to protect this portion of the cliff was first thought of, but had to be abandoned on account of expense, and the author then decided to erect three slanting groynes presenting an obtuse angle to the direction of the prevailing winds. These groynes were constructed of double sets of piles in line, with roughly dressed forest trees lying horizontally between them. The horizontal timbers were bolted, and otherwise fastened to the piles, and each groyne was strengthened by struts, and backed by large boulders and blocks of concrete.

Soon after the erection of these groynes the shingle began to accumulate on the lee sides, being thrown over in stormy weather, and retained all along the toe of the cliff, which soon became completely protected from the sea, even at the highest tides. The work was finished in the summer of 1898, and on April 11th, 1899, an examination revealed the following facts:—At the time of erection the sea end of the most eastern groyne was 4 feet 6 inches above the sand; this had increased to 6 feet 9 inches, so that the scour had taken away 2 feet 3 inches. At the same time a very

heavy accumulation of beach, over 7 feet in depth, had collected on the lee side of this groyne at and above high water mark. Similarly with the middle groyne 1 foot of sand had scoured from the sea end, but, as with the last named groyne, a large quantity of shingle had been thrown completely over to the lee side, where it had been retained near high water mark. The third or western groyne showed a scour of six inches only, and the shingle had collected, as it had at the other groynes, both on the windward and lee sides—the bank having risen in places as much as 5 feet. It is more than two years since these groynes were put down, and the results have up to now been satisfactory, in that the road is still intact, though at the time of commencing the work there were only a few feet between it and the sea, and several exceptionally severe storms have visited the coast.

The following observations may fairly be made with respect to the action of these slanting groynes:—

1. They have collected beach both on the windward and lee sides, and have caused a heavy bank to accumulate at and above high water mark, where there was previously no beach at all.

2. The sea no longer reaches the toe of the cliff; this is proved by the grassing over of that portion of the cliff.

3. They cause scouring action to take place at their sea ends which evidently stand too high above the level of the sand.

From these facts it would seem that the upper portions of the groynes should be left to do their work of retaining the shingle beach in its present position, and that the sea ends should be cut down until their scouring action is reduced to a minimum.

It is observed, with respect to this particular portion of the Glenbeigh shore, that the encroachment, checked at one

particular point, is now very marked on either side of the slanting groynes, and steps will have to be taken immediately to stop this out-flanking movement of the sea.

In 1898 the author decided to adopt the Case system at Glenbeigh, and nine of the low groynes were put down last year; and the work, which was in charge of Mr. Cecil B. Case, has without doubt greatly improved the condition of the shore between mean sea level and low water mark.

The three slanting groynes above described were never expected to do more than the work of protecting a certain weak spot, and in this they proved entirely successful; they could not be expected to *improve the foreshore as a whole.*

The Author's Extension of the Case System.

From a close observation of the action of these slanting groynes and others on the south coast of England it has occurred to the author that the principle of slanting groynes might with advantage be applied to many shores as an extension of the Case system, especially in those places where it is undesirable or impossible to resort to stepped walls on the ground of expense.

The difference in the action of the two systems is very apparent. The Case groynes act on the lateral currents by slowing them down, and causing a deposit of detritus which would be otherwise lost; they also encourage the carrying of particles shoreward by diverting the long-shore currents in that direction.

The author's curved slanting groynes rely more on the agency of the waves, and so trap and retain the shingle which is thrown over from windward to lee.

The author has repeatedly watched the effect of a dead on-shore gale on slanting groynes, and he has invariably observed that much of the shingle—often consisting of

blocks weighing 5, 10, or 20 lbs.—is bodily carried over the top of the groynes, and retained *on the lee side, where it is wanted for the formation of the "full."* This retention is due to the circumstance that the slanting groynes, running diagonally up the beach, are inclined at a *much flatter gradient than those groynes running at right angles to the coast-line,* and, therefore, the retreating volume of water which causes the scour has less power to carry away the deposited shingle. On the same principle a very rapid mountain torrent will carry down huge boulders, which would rest peacefully for ever at the bottom of the same river, when it emerges into flatter lands, and winds amongst the lower valleys.

A glance at the model exhibited and the sketch plan of typical shore line would indicate the author's system, and its adaptability to the Case system. The slanting groynes recommended from a continuance of the Case groynes from mean sea level up to high water mark, and they are constructed on much the same simple principles, but the timber has to be of heavier scantling because of the pounding action of the sea in rough weather. Here it may be observed that, in selecting our timber, we must be guided by the position it is to occupy on the shore as well as by the size and quality of the shingle composing the beach. Fig. 15.

Experience shows that, when acting on timber—especially vertical piles—the sawing action of sandstones is worse than that of rounded flints, though the latter may have a more erosive effect on the faces of sea walls. Where piles have been driven anywhere in the neighbourhood of high water mark, in localities where there is a heavy travel of beach, it will often pay to protect the *windward piles,* at the portions where they are most subjected to this sawing action of the shingle, by angle iron or, better still, by nail-

ing on planks, which can be renewed when worn through. This may seem a small point, but it is one which should receive attention. The life of the windward piles may be doubled or trebled by attention to this detail, and much expense of groyne maintenance may be saved, for it is always costly work driving fresh piles.

The shingle action does not affect the horizontals nearly so much, and when planking gets worn it can so easily be replaced.

In general design, construction and application, the author's form of curved slanting groynes may be thus shortly described, and it may be at once stated that this type of groyne is intended to form a continuation and extension of the Case groyne.

Rows of piles 8 in. by 4 in., or other scantling suitable for the locality, are driven in pairs in a line curving gradually from the termination of a line normal to the coast-line at mean sea level (*i.e.*, the end of the Case groyne forms a tangent to the curve at mean sea level), a suitable space being left between each pair for the insertion of planking—the distance between each pair being chosen with reference to the general conditions obtaining in any particular case. Fig. 16.

As the curve is never to be a sharp one, the insertion of planking can be easily managed by slightly bevelling off both piles and planks as shown in detail drawing. As soon as the curve has reached a point where its tangent coincides with the required slant, the groyne is continued in a straight line as far as may be deemed necessary, and this would generally be up to the face of the wall or cliff.

In laying out the groyne the direction of the prevalent wind has to be chiefly considered, as the utility of the groyne depends almost entirely on the force and direction of the waves.

It will be seen that in designing this groyne, as a continuation of a low groyne, the author has recognised the importance of avoiding anything like an abrupt angle, and he has therefore adopted a curve which for all practical purposes may be a portion of a circle, ellipse, parabola or hyperbola. As soon as the shore has settled into its proper elliptical form, or an approximation thereto, the line of the curved groyne will be a curve upon an elliptical surface, the equation to which curve the author is not prepared to work out. It is merely necessary that there should be no abrupt angle anywhere.

The planking is removable and adjustable, and the sea ends taper down till at the sea end of the curve they touch the land ends of the Case groynes. There is thus one continuous groyne consisting of low Case groynes between low water mark and mean sea level, and the author's partly curved groyne from mean sea level to the wall or cliff, and in its whole course there is no abrupt angle of any kind, and nothing to present a sufficient obstruction to cause a scour.

The advantages of the double system appear to be:—

1. The collection and diversion of material travelling between mean sea level and low water mark, by the Case groynes, this action depending mainly on lateral currents.

2. The catching and retaining of beach near high water mark by the high slanting groynes, which need never cause scour because they can be regulated to meet the requirements of the case almost as easily as the low groynes.

3. Accumulation of beach takes place both on the windward and lee sides.

4. The slanting portion of the groynes may in many instances take the place of breastworks or walls, and would be far less expensive.

5. The cost of Case groynes is about 10s. 6d. per foot run,

and the curved slanting groynes, of which in nearly every case comparatively short lengths would be required, would be from £1 to £2 per foot run.

The Travel of Material.

There is probably no subject connected with foreshore protection upon which expert opinion is more divided than it is upon the travel of beach and other material round the coast-line. That there is always *a* travel of material round every portion of these islands is conclusively proved by the discolouration of the sea all along the shore in rough weather. The discolouration varies with the locality, being of a chocolate hue off the Holderness coast of Yorkshire, where the cliffs are composed of reddish mud and clay, and of a milky hue outside the chalk cliffs of Dover. Every sandy coast exhibits a yellow discolouration, and if a pailful of the water be taken and allowed to stand a thin sediment of sand will be formed at the bottom of the vessel.

In every case the particles held in suspension give colour to the water, and all are ultimately deposited *somewhere;* they may be carried out to sea by currents, and assist the growth of submerged banks, or they may drift along shore and be deposited upon some promontory steadily advancing seawards; or again, they may help to give work to the redges by adding to the silt at an estuary or mouth of a harbour. The Yorkshire coast provides us with an excellent example. As is well known the whole of the coast between Bridlington Bay and Spurn Point is steadily wearing away at from 3 to 10 feet per annum. Probably millions of tons of material eroded from this long line of coast are annually carried down south. Much is deposited in the neighbourhood of Spurn Point, contributing towards the silting up of the Humber estuary; vast quantities no

doubt pass the estuary, and travel down the Lincolnshire coast until Skegness is reached; here Gibraltar Point, rapidly pushing its way out into the North Sea, in a south-easterly and easterly direction, catches a great deal of the silt, and probably most of the remainder settles on the numerous shoals which abound in the Wash. It is also possible that much of this travelling silt may leave the coast altogether, and find a resting place on the Dogger Bank—the great submerged fishing bank lying between England and Norway.

All this of course refers chiefly to the lighter portions of detritus. It is a very vexed question whether heavy material, shingle, &c., is or is not carried by currents or waves round headlands in deep water. Two points are particularly under dispute:—

1. Can shingle be moved in deep water say 30 or 40 fathoms?

2. If it is so moved, is the motion due to the action of *waves* or tidal *currents*, or to a combination of both?

A good deal of expert evidence has been forthcoming upon these questions, but the absence of anything like unanimity forces us to acknowledge that we are still rather in the dark, and have yet much to learn.

Professor L. F. Vernon-Harcourt speaking at a meeting of the Society of Engineers in London, on June 5th, 1899, said "He thought it must be admitted that the motion of shingle or sand must be due to the action of the waves, except where there was a very strong tidal current in a narrow channel; and it was doubtful whether the waves could produce drift at any great depth. It had been suggested that drift took place at a great depth, but it required very careful investigation to find out whether such drift really took place in deep water." Mr. R. F. Grantham, speaking on the same occasion, expressed the opinion

that the question of the depth of water in which it was possible for shingle to travel was a very difficult one, and he did not think it had ever been solved.

In support of the author's statement as to the diversity of opinions existing amongst scientific authorities it may be interesting here to quote a few extracts which were collected by Mr. A. R. Hunt.*

Sir John Coode was of opinion that "shingle accumulates on any beach with off-shore winds, whilst it is carried off or scoured away during on-shore winds, and more especially by the ground-swell which follows." Mr. G. H. Kinahan, writing of the east coast of Ireland, between Carnsore and Dalkey, says:—"West and south-westerly winds (*i.e.*, off-shore winds) generate ground swells, which usually cut out the beaches. . . . Ground swells with east winds (*i.e.*, on-shore winds) sometimes seem to assist in filling in the beaches, but with north-easterly winds they cut out."

Sir George Airy held that "The progression in smallness of the pebbles pointed to the direction from which the current or fluctuation must have transported them. . . . They must have been transported from the end of the bank, where they were large, towards the end where they were small."

Admiral Spratt on one occasion put overboard five bags of clinkers, weighing from 3 lbs., 4 lbs. and 5 lbs. to a few ounces, and on visiting the spot a fortnight afterwards to examine the effect of wave action, he found 450 yds. to the leeward the largest pieces of clinker nearest the point of starting, one weighing $3\frac{1}{2}$ lbs. and the other 2 lbs.; at 700 yds. and 800 yds. they weighed less than 1 lb.; and at 1,500 yds. and 1,600 yds. from $\frac{1}{2}$ oz. to $\frac{1}{4}$ oz. only. Thus the heaviest and largest pieces did not travel the farthest, but the contrary.

*The Scientific Proceedings of the Royal Dublin Society, Jan. 7, 1885.

In opposition to these two last authorities Sir John Coode was of opinion that "The cause of the large shingle being found at what is called 'to leeward' upon any beach is due to the fact of the large pebbles moving more readily than the small." In this he is backed up by Mr. Redman, who says, "Undoubtedly the largest shingle travelled to leeward." Then Mr. T. Mellard Reade says, "It was not, as Sir John Coode supposed, that the large stones were the more easily moved, for the reverse could be readily proved. . . . The large stones, in fact, travelled up a lesser gradient, and consequently to a greater distance."

Sir A. Geikie held that, "A prevalent wind by creating a current in a given direction, or a strong tidal current setting along a coast-line, will cause the shingle to travel coastwise, the stones getting more and more rounded and reduced in size as they recede from their sources. The Chesil Bank, which runs a natural breakwater 16 miles long, connecting the Isle of Portland with the mainland of Dorsetshire, consists of round shingle which is constantly being driven westward."

Sir Chas. Lyell, on the other hand, "Admitted the apparent paradox of the largest pebbles at the Chesil Bank being found to leeward, or farthest from the source whence they were derived, as he took it for granted that they did come from the westward. . . . Throughout the Chesil Bank the pebbles increase gradually in size as we proceed south-eastward, or as we go farther from the quarter which supplied them."

Thus we fail to come across many traces of unanimity amongst these writers, even on this question of beach formation and the travel of large and small specimens; and when it comes to the *depth* at which shingle travels, we also find startling discrepancies or differences of opinion upon what one would think should be matters of fact.

For instance, Mr. J. M. Rendel's opinion was "That shingle could scarcely be moved by the heaviest waves at greater depths than three fathoms." Sir E. Belcher said that "The waves during heavy gales exercise a power at very great depths; he had seen evidences of it in water 14 fathoms deep. He thought the tide current did not affect depths of more than 12 or 14 ft." Against this, again, there is the opinion of Mr. Joseph Gibbs, who considered that ". . . the movement of the beach in question was not so much due to the ordinary flow as to what might be termed submarine currents, which had the power of carrying pebbles along the shore at great depths until the waves cast them up as shingle."

Author's Prospecting Grab.

The most satisfactory method of getting fair and indisputable evidence as to the travel of shingle and general detritus is by taking up specimens from the bottom of the sea, at all places where there is any doubt, or where it is thought such material might by any possibility travel. An examination of such specimens will show whether they have been torn from a state of quiescence, or whether the attrition of the surfaces is such as to clearly indicate motion along the sea bottom.

In order to easily and rapidly obtain specimens from deep water the author has designed a prospecting grab which, when constructed on a suitable scale, is easily carried about from place to place.

The apparatus consists of two equal and similar cheeks which automatically close when bottom is reached. Some of the advantages which may be advanced in favour of this grab are:—Simplicity and lightness, the absence of all levers, pulleys, concentric drums and wheels, the certainty of action and ease with which repairs can be effected. It is

worked with a single rope or chain on which the fathoms are marked, and can be ballasted to suit the work it is required to do. When used for prospecting, the disc which first touches the bottom is smeared with tallow or some other adhesive substance, after the manner of sounding leads, for the purpose of collecting fine particles of sand or gravel which might possibly escape through the teeth in drawing the instrument up through many fathoms of water. This grab which, for prospecting purposes, may be made from a hollow cylinder of copper or iron 12 or 15 inches in diameter, can also be used on a large scale for dredging up sand or other soft material.

There is one point to which reference must now be made before leaving the subject of travelling material; it is the reckless and wholesale carting away of sand and beach for agricultural, building, and other purposes. It is quite usual to find the authorities at, say, a sea-side watering place in a state of the greatest anxiety about the accumulation of beach and the improvement of their foreshore, and yet to discover that these very people are making a large profit by deliberately selling the highly prized material at the rate of many hundreds of tons per week. There would be some sort of reason in their action if they would only admit that they prefer to pocket a few pounds per week to permanently improving their foreshores.

But this is just what they do not admit. They sell boldly and steadily, and then, having denuded the unfortunate shore of enough material to build a good sized town, they go round and look at the "place," and assure one another in solemn tones that "the beach is decreasing." Or again, having allowed carts to take away thousands of tons of a certain "full" of beach, *at a certain definite spot*, the sea has perhaps taken advantage of that weak point, and an "accident" has happened—the land has been

flooded, and perhaps inner walls and houses have been damaged. Then there is excitement, the usual meeting is called, and a number of gentlemen visit the scene of disaster, and the sum total of their remarks amounts to "Dear me, there's a considerable weakening of the shingle bank; we really must call in an expert." In this connection it may be remarked that in a very large percentage of cases the "man in the street" considers himself qualified to deal with any problem connected with foreshore protection, and the author has frequently heard the most fearful and wonderful statements and proposals made by persons whose only qualifications appear to be residence within sound of the waves, or the possession of a pleasure boat. The expert is not, as a rule, called in till some extensive damage has been done, whereas had he been called in a few months or weeks earlier he might, at comparatively trifling costs, have averted the disaster.

The whole question of foreshore protection is one which literally bristles with difficulties. We are all so much in the dark, and have so much to learn in many directions, and it is often so impossible to arrive at sufficient data. Then again, the opinions given by the "oldest inhabitants" nearly always differ materially *as to matters of fact*—so that the bewildered foreshore engineer, though standing on the beach, is really at sea as to what Father Neptune has been doing within, say, the last 40 or 50 years.

For present purposes it will be sufficient to give three or four instances of this carting away of shore material.

At Glenbeigh the cultivators of the soil use sea-shore sand to a very large extent. The sand contains a percentage of lime, and its nature is such that it helps to disintegrate the peaty land and render it fit for the production of potato and other crops. For the past forty years there has been a constant friendly strife going on, between

these tenants and the owner of the property, as to the locality from which the sand should be taken—the tenants, with rare perversity, but with no malice aforethought, always hitting upon the very most important spots, and digging holes in places the owner wishes to protect.

At Lowestoft, the authorities called in the late Mr. Edward Case—and adopted his system. Shortly afterwards, having placed the shore practically in Mr. Case's hands, they decided that they would build a wall. This they actually did, without making any reference to Mr. Case, and they used in the construction many thousands of tons of shingle collected by the Case groynes. Then they were quite upset to find that the shingle which they had taken away was no longer on the shore! Even Corporations must not expect to keep their cake and eat it too.

At Youghal, where the Case system has been adopted, the carting away of sand has been one of the many difficulties. On that shore there is practically no proper "full" of beach, so that the extraction of many cartloads is little less than a crime.

At Bray, north of the harbour, there is a very heavy full of beach which the owner of the foreshore is rapidly disposing of to the detriment of the Dublin, Wicklow, and Wexford Railway Company's Line. Some two years ago the author found a gap 100 feet long by 50 feet wide, and 6 or 7 feet deep, had been made right through this full at a distance of some hundred yards to the north of the harbour wall. Thanks to good luck, and the absence of severe on-shore gales, this gap merely served the purpose of an eyesore for a long time; but last month a storm occurred during a fairly high tide, and, as was to be expected, the sea found its way through the gap, and reached the light trespass wall at the toe of the railway embankment. Now this would not have happened had not the

wide gap above described been made in the shingle "full." So that we come to the plain fact that the action of the owner in destroying his foreshore is a direct menace to the integrity of the railway company's line.

The author believes that it is a legal axiom that you may not benefit yourself or your own property if, in doing so, you materially damage your neighbour or his property. For example, we will suppose that A builds a long, solid masonry groyne for the purpose of protecting his foreshore or collecting material, and that it can be indisputably proved that the structure is highly detrimental to B's adjacent foreshore, then A can be compelled to remove his groyne.

Or take another example—A owns a house in the middle of a row. He cannot say "This house is mine, I will pull it down," for if he does so the houses on either side will fall down and there will be a transgression of one of the Urban Servitudes, "*oneris ferendi.*" He must make certain arrangements, at his own expense, for propping up his neighbours' houses before the law will allow him to pull down his own house.*

The case at Bray is very similar. The owner of the foreshore says, in effect—"This shingle belongs to me and is on my property, and therefore I can dispose of it in any way I please;" but the answer is—"If you do dispose of this, the only barrier between the sea and your neighbours' property, you will seriously jeopardise the safety of the railway line."

* For many years past there appears to have been a great difference of opinion among the judges as to the law of support, and reference should be made to the cases of "Kempton *v.* Butler" and "Latimer *v.* Official Corporation Society." Probably the most important case is that of "Dalton *v.* Angus," which was taken to the House of Lords in 1881. Their lordships then decided that the owner of an ancient building has a right of action against the owner of lands adjoining, if he disturbs his land so as to take away the lateral support previously afforded by that land, and they gave a decision in favour of plaintiff. This practically reverses the law, as previously understood, and must be taken to be the law now.

The Bray case is rather a serious one, for not only is the railway threatened, but also the northern wall of the Bray Harbour, to say nothing of the land lying to the west of the railway line.

In view of the number and complexity of the problems involved, and the importance of having reliable information upon which to go on occasions of rapid sea-encroachment affecting valuable property, the author has suggested the advisability of establishing a Department of State, or branch of a Department, to which the careful and thorough supervision of all foreshores should be entrusted. He brought the matter forward at the British Association meeting at Dover the year before last, and the following is an extract from his letter to *The Times* of October 14th, 1899:—

"At the present time there is absolutely no official and reliable record of the changes annually taking place round our coasts, and these changes are constantly affecting buildings and other works which have been carried out at a large outlay of public money.

"Lighthouses, coastguard stations, roads and other necessary structures are maintained chiefly at the national expense, or by county councils and local authorities, and it would, I feel sure, be advantageous if annual surveys were taken and returns given which would enable engineers to take the necessary protective steps before any serious damage had occurred.

"The Admiralty charts are excellent for deep-sea soundings, and for purposes of navigation, but they contain very little information on the question of currents affecting the coast-line, and it would require the careful attention of a department, or district branch of a department, to keep a satisfactory record which could be relied upon when the time for action arrived. As matters stand at present it is, as a rule, only at the 11th hour, and after considerable damage

has been done, that an engineer is called in, and the mischief is then probably so considerable that only a large expenditure of money can save the situation; whereas, had the note of warning been struck a year or two sooner the catastrophe might have been averted at comparatively trifling cost.

"Amongst the duties of the suggested department the following may be enumerated:—(1) The systematic and repeated taking of sections, over the same lines, on all doubtful shores, as well as contours of high water, low water, and mean sea level lines; this latter is very important, as much damage is done during storms taking place at half tide. (2) The taking of soundings. (3) Calculations based on observations respecting the varying rates and directions of currents at high water, low water and mean sea level. (4) Observations as to the velocity and *vis viva* of waves. (5) Observations on the travel of beach, sand, and other material, especially round headlands, piers, breakwaters, and across bays and the estuaries of rivers.

"As one of the superintending engineers of the late Mr. Edward Case, I had frequent opportunities of discussing the question with this gentleman, whose system of groyning is now so well known and appreciated at many places in England and Ireland, and we invariably came to the conclusion that the whole question should be dealt with as a national one, and that all shores—save alone rock-bound coasts, the alteration in which is so slow as to be practically nil—should be closely watched by the State.

"The Ordnance Survey maps are, of course, admirable, but they only show the changes in high and low water marks at long intervals of time. What we require is a succession of observations by means of which any mischief may be readily detected and dealt with in its initial stage, on the 'stitch-in-time' principle.

"Did space allow, I could multiply examples of instances where acres of valuable land and house property have been lost, an engineer only being called in at the last moment, when some county road, building, or a railway line was in jeopardy. This kind of thing is hardly fair to the profession, and is analogous to calling in a doctor to see a moribund patient.

"Cases like this would not occur if the State took the matter up, for the competent men in charge of the department would at once give notice on the approach of danger, which might be threatening not only the immediate foreshore owners but the owners of low-lying property far inland, and the proportion of cost to be borne by all interested in the necessary works could then be determined. Procrastination—that worst enemy to economy—would be avoided and everyone would benefit.

"How such a department should be constituted, and whether it should be under the control of the Admiralty, the Board of Trade, or the office of Woods and Forests, are questions quite out of my line, but, from observation and experience, I believe that a large saving in the future would result from the adoption of some such scheme as I have suggested."

Soon after the appearance of this letter the author got into communication with the Board of Trade and the Board of Agriculture, and received the following replies:—

"7 Whitehall Gardens,
"London, S.W.,
"*17th October*, 1899.

BOARD OF TRADE (FISHERIES AND HARBOUR DEPARTMENT).

"SIR,

"With reference to your letter of the 4th inst. relative to a suggested establishment of a department to under-

take various duties in connection with the protection of the coast of this country against erosion by the action of the sea, I am directed by the Board of Trade to inform you that it appears to the Board that the proposal, if carried out, would entail very considerable expense, and would probably necessitate the revision of many Acts of Parliament under which the coasts are now protected.

"In all the circumstances of the case the Board of Trade are disposed to think that the scheme is not feasible at present.

" I am, Sir,

"Your obedient servant,

"T. H. W. PELHAM.

"R. G. Allanson-Winn, Esq."

"Board of Agriculture,

"3 St. James's-square,

"London, S.W.,

"*6th January*, 1900.

6064.

"No. B. 1899.

"SIR,

"I am directed by the Board of Agriculture to advert to your letter of the 9th ult., and to say that the Board have read your communication with much interest. The only portion of the work which you propose should be undertaken by the Government which it would be practicable to entrust to the Ordnance Survey is that which relates to the systematic and repeated taking of sections and contours of all shores subjected to change, and the Board do not think that it is at all probable that the Treasury would feel justified in providing at the public cost for the considerable expenditure requisite for the purpose.

"The Board might, however, suggest that your proposals

might be brought under the notice of their Lordships and the Admiralty.

"I am, Sir,

"Your obedient servant,

"P. G. GRAIGIE,

"*Assistant Secretary.*

"R. G. Allanson-Winn, Esq."

About this time the complications in South Africa began to absorb public attention to the exclusion of all other topics, and it was impossible to then pursue the matter any further.

Early in 1899 a Committee was appointed by the Council of the British Association, with Sir Archibald Geikie Chairman, to consider further the question of the erosion of coasts round the British Isles, already reported on to the Association by previous Committees; and this Committee has arranged, by the kind assistance of the Admiralty, to obtain returns of changes noted from time to time in the shores of the several coastguard districts along the coast of any protective works which may be carried out, and of the effects produced by such works.

The above appears in a footnote in the "Minutes of Proceedings of the Institution of Civil Engineers," Vol. CXXXIX., Session 1899-1900, Part I., and doubtless a step in the right direction has been taken; but it does not go nearly far enough. It is obvious that the coastguards are not in a position from their training and equipment to take the sections, make plans, and keep records in such a manner as would be serviceable to engineers when called upon to execute works.

It would, for instance, be very difficult for a coastguardman, however intelligent, to give a satisfactory account of the "effects produced" by protective works unless he had

taken sections, &c., when the works were started, and could compare them with later sections, &c.

It seems to the author that if we can now ascertain certain details and facts connected with inland measurements from the Ordnance Surveys, and can also obtain from the Admiralty Charts the Deep Sea Soundings necessary to navigators, it is little short of an anomaly that we should be thus left in the dark in the matter of the coast-line, which in many places is undergoing such rapid and continuous change.

What is really wanted is a scientific and continuous record of all changes in the coast-line, that border-land between high and low water marks. Few seem to realise that this strip of at present neglected land extends for some thousands of miles round these islands, and that in the aggregate the interests assailed are very large.

In Germany the State is assisting scientific experiments now being made respecting the changes taking place in many of the larger rivers, with the view of ultimate saving and improvements. Why, then, should not the authorities in these sea-girt islands take some steps in the right direction. "Britannia Rules the Waves" until they actually touch her shores, and then the positions are frequently reversed, as we see by the flooded lands, silted-up harbours, broken down sea walls, and eroded cliffs, which are to be found all round the coast.

It should be as easy to find out (by reference to such records, plans, and sections, as have been suggested) the existing and previous condition of any given shore frontage as it is now to ascertain the length of Sackville-street or the size of Stephen's-green.

The question is admittedly one of great interest and importance, and, as such, it should be worthy of scientific and systematic attention. The author considers that he

will be very fortunate if in the future years of his life he is enabled, by diligent study and repeated experiment, to throw a somewhat stronger light on even a few of the many intricate problems involved in this particular branch of Civil Engineering.

In opening the discussion on this paper Mr. Allanson-Winn made the following introductory remarks:—

When the practical utility of a discovery or invention has been fairly demonstrated there is sometimes a tendency to stagnate and refuse to recognise the fact that there may be other useful auxiliary methods in no way clashing with the original idea, and the adoption of which, in certain circumstances, may be highly beneficial.

The author has recently received communications from gentlemen who have read his paper, and who object to the slanting groynes as being erected at high water mark, and therefore certain to create scour. The present opportunity offers itself as a fitting one for adding a few remarks which may help to elucidate the question.

It will be conceded that there must always be *some* obstruction at high water mark. The line of demarcation or boundary between the sea and land always exists, whether in the form of a sand-dune, a shingle bank, esplanade wall, line of sheet piling, or stepped breastwork wall.

If, therefore, it can be shown that a particular form of high water protection answers the purpose of collecting and retaining shingle in certain situations, there can be no reason in objecting to it merely on account of its name. The fact is that, as strong advocates of the Case system of low groynes and equally strong opponents of the ordinarily accepted high groynes, as erected at Hastings, Brighton, and elsewhere, we are, not perhaps unnaturally, apt to regard with disfavour anything in the nature of a groyne anywhere near high water mark.

As regards the form of slanting groynes suggested by the author, the idea was to use them as accumulators or traps for the shingle at points on the shore where the Case groynes do not reach, but which, nevertheless, have to be protected. The elliptical concrete wall, or similarly designed embankment of timber, has been successfully applied in conjunction with the Case groynes, but a close examination will reveal the fact that the slanting groyne is in reality a modification of the stepped wall, each step of which touches a point on the curved and slanting groyne. The protection afforded by the slanting groyne may not be so effective as that given by the stepped wall, but, where there is a heavy travel of beach and a long line of coast to be protected, and limited means at the disposal of the engineer, it is suggested as a valuable auxiliary.

The idea of using slanting groynes is not by any means new, so that the author disclaims any title to originality under this heading; there appears, however, to be some indication of novelty in the idea of a curved groyne gradually working up from a low groyne until it has reached the limit of high water mark, and the advantages of such a groyne may be best worked out theoretically by first of all considering some of the more important phenomena and conditions obtaining on the generality of shores.

It will be at once conceded that the steepest line of descent on any shore is found by taking a section of the shore at right angles to the coast line. It follows, then, that, when originally constructed, all groynes running at right angles to the coast line have, on either side, the steepest possible gradient on that portion of the shore.

It will probably be also admitted that, if the groyne be run out in any other direction whatever on either side, the gradient will be less steep, because the line will run diagonally up and down the beach. The maximum of steepness

is shown by the sectional line at right angles to the coast line, all other lines gradually diminishing in steepness from 80 up to 90°, when the minimum is reached at dead level with the original point of starting.

It can also be easily proved by elementary mechanics that bodies more readily slide down steep inclines than they do down inclines which are not so steep, and that, where the action of water is concerned, heavy boulders and shingle of all sizes are readily moved in rapid rivers, and that they are not moved at all, or only very slightly, in sluggish rivers.

Following up this line of reasoning we arrive in a very few steps at the conclusion that the important point is *the steepness of the gradient,* and that, where scouring action is to take place, it will, *ceteris paribus,* be worse on the lee side of those groynes which run down the steepest gradient.

It can also be demonstrated that the less steep the gradient the longer it takes for the water to run off by filtration or percolation or by running down the lee side of the groyne, and that, therefore, material of all kinds has a better chance of being retained where it is wanted.

It can also be readily shown that those proposed slanting groynes (being constructed as described) are not of the nature of solid immovable structures, and can always be lowered or raised to meet *the circumstances of the case at any moment,* and that, therefore, they must not be included in the list of dangerous solid obstacles at high water mark.

To turn to the practical aspect of the matter. In 1896, during the author's absence from England, a couple of box groynes were run out at right angles to the shore line at a portion of the Glenbeigh coast, where the cliffs were undergoing very rapid erosion. These groynes not only

failed to collect material but caused the formation of bays or indentations of the cliff on either side.

Soon after this Mr. H. M. H. Collier put down a few slanting groynes composed of railway sleepers driven in as sheet piling. And this may be regarded as the first really scientific effort made to protect this portion of the shore. Owing to the inadequacy of funds at his disposal, and the very slender nature of the work, these groynes were gradually swept away by storms, but not before they had given very marked indications of success.

In 1898 the author erected three slanting groynes of a more solid form of construction. There was practically no shingle at all at the toe of the cliff when those groynes were completed in the summer of 1898. Repeated observation showed that shingle was continually thrown over and retained on the lee side of these three groynes, and that the improvement has been continued, and is still continued, is clearly demonstrated by the existence of a heavy bank of shingle effectually protecting the toe of the cliff, which is now grassing over in many places. This shingle was not there in 1898; it is there to-day, and this actual fact should go far towards backing up the author's opinion that slanting groynes will, in certain situations, catch and satisfactorily retain shingle.

We have to admit that it is common sense, backed by technical knowledge and experience, which carries us through the most serious engineering difficulties.

In the case before us we have a set of slanting groynes of very rough and ready construction, and most imperfect in design, and yet it is shown that they have been instrumental in safe-guarding a portion of the coast.

Common sense points to the probability that similar groynes more scientifically designed will be even more effective, and the author in designing these partly curved

slanting groynes has kept carefully before him the points which have seemed of greatest importance—viz.:—

Trapping and retaining of shingle.

Reduction of scouring action.

Rapidity of lowering and heightening.

Simplicity of design and economy.

Early last year a gentleman, presumably an engineer, signing himself "Traveller," contributed an interesting letter to "Engineering," in which he wrote:—"I do not think the advocates of special systems of groynes usually sufficiently bear in mind the many factors which govern the form of the foreshore, such as the waves, the direction from which they come, the material, and size of such material of which the foreshore is composed, the quantity of drift, range of the tide, position with regard to shelter, prevalent winds, the effect of sea walls, and many other things." There is a good deal in these remarks, and it is to be regretted that the gentleman did not sign his name, as he might then have been invited to take part in this discussion.

No doubt it is highly important for specialists in sea work to be ever on the alert, as there are few branches of Civil Engineering where disappointment so frequently follows the expenditure of money as it does in the case of foreshore protection.

If we build a bridge, or a retaining wall, or a house, there is a reasonable hope that, given immunity from earthquakes, waterspouts, or foreign invasion, the work will at any rate outlive the whole of the present generation. But with sea coast protection works this is by no means the case, for the engineer, often cramped in his designs and estimates through the limited means at the disposal of his clients, finds he has to fight a most relentless foe with very indifferent weapons. In short he has

not to carry out what he feels certain is necessary to insure protection, but to make the best job he can of it with very inadequate means.

The author has been for so long advocating the claims of the "Case System," as being better than any other, that is hardly necessary for him to disclaim any intention of supplanting that system, which seems to him to stand alone in its originality of conception. What he wishes to do—and his humble efforts have been entirely in this direction and with this object in view—is to think out and devise any method which, without clashing in any way with his late friend's invention, may be profitably used as an auxiliary in certain situations.

Respecting the establishment of a Department of State to look after the coast line of the British Isles, it is instructive to note how thoroughly matters of this nature are gone into in Germany, and how anxious the State is to encourage scientific experiments and discoveries. The author is informed that, at the Dresden Technical School, a large experimental station has been established, entitled the "Flussbau Labatorium," or river building laboratory, and that here experiments are being carried out by Professor Engels, who is directly acting under and with the support of the Government. Models of important rivers are here made, and the Professor is enabled, by regulating the supply of water and by the introduction of different coloured sands, to give a good idea of what happens in times of flood and in times of drought; where silts are likely to accumulate, and where banks are likely to be scoured out and destroyed.

The contours of the channel beds as well as the shore lines of many of the great German rivers have been plotted with great accuracy, and Professor Engels has been enabled to duplicate, in miniature, every breakwater,

embankment and curve in the more important rivers. The idea is that by *testing* certain alterations, such as reclamation, building of dams, &c., &c, in the model, engineers may be forewarned and so avoid the useless expenditure of money. All this shows that the German Government is keenly interested and alive to the importance of preventing waste, and so improving the condition of the Fatherland.

No such attention is given to that long strip of "No man's land" which surrounds Great Britain and Ireland between high and low water marks. It is allowed to waste away or accumulate according to circumstances. No scientific records are kept, and the most that has been done is to ask the coastguards to "note the effects produced by protective works," which, in the author's humble opinion, they are hardly in a position to do.

Since calling attention to this subject in September, 1899, the author has frequently discussed the matter with parties interested in foreshore protection works, but the South African War has effectually put a stop to any further communication with the authorities either at the Treasury or Admiralty.

Mr. E. K. Dixon, County Surveyor, South Mayo, desired to make the following observations:—

As a provincial member of the Institution he was fortunate enough to be present at the meeting at which the above most interesting and valuable paper was read by Mr. Allanson-Winn. It was particularly pleasing to him that on his first visit to the Lecture Hall such an important subject as "Groyne Construction" and its practical application to foreshore protection should be so ably treated. The members present, and those who may read this paper, will, he was sure, feel greatly indebted to Mr. Winn for making the details of an intricate subject so very clear.

He felt that it really required a specialist to make any observations on this particular branch of Civil Engineering, inasmuch as the system of "Low Groynes" protection may be considered of very recent origin, as compared with the old or "High Groyne" system.

An engineer engaged as he was, on miscellaneous works of a very varied character, had but very little time to study or experiment upon any particular branch of his profession. However, it seemed to him that every member should endeavour to contribute to the Institution any little practical knowledge he might possess, for the benefit of the whole, and so keep up the tone and standard of its proceedings.

He believed that the paper under consideration would occupy a foremost place among the best papers of the Institution in London; indeed, every portion of it bristles with practical facts, considerations, speculation and food for much thought. Although never specially employed in connection with any large scheme for the protection of the coast-line from sea encroachment, still he had during his practical experience had to deal with questions of a similar kind on the east coast of England and on the west coast of Ireland; also, he had studied the action of the sea at many other points of the coast-lines of these countries. He desired only to draw attention to a few points raised in Mr. Winn's paper. It did not seem quite clear from the text, at what distance apart low groynes were usually placed, or what governed their actual number; but he presumed the author left this as a problem to be determined in each locality according to the varying circumstances. It would appear, however, both from theoretical and practical consideration, that the greater the number of low groynes employed (consistent with economy), the greater and quicker would accumulations occur, within

certain limits. Further, it might prove interesting if experiments could be made to ascertain if groynes placed at right angles to, and in connection with, low groynes, between mean and low tides, would increase, with greater certainty and more quickly, the deposit desired.

With regard to the subject of lateral foreshore currents, there could not be any doubt that when such were chiefly in one direction, denudation must occur, and unless such removal of solid matters could be counteracted by a supply of material brought by opposing currents from other places (at their expense), the foreshore must suffer at the place in question. Now, nature in many places furnished a sort of equilibrium action of this kind, which kept the coast-line intact; and then again, the opposite extreme occurred, where in bays, and indents, along the coast, accumulation of sand, etc., were to be seen. The former case was illustrated at Achill Sound, on the west coast of Ireland, where a swing bridge with long approaches had been erected to connect the island of Achill with the mainland. The approaches or viaducts were composed of heavy dry stone rough fillings in the form of banks finished off with sloping pavements, bermes, floors, etc. The bridge opening consisted of two 45 feet spans. The tide ran in and out under this bridge at the rate of 8 or 9 knots an hour. The foundation to one of the abutments of the swing bridge was of a very doubtful character, and there is no doubt but that this part of the structure would long ago have collapsed if it had not been for the to and fro action of the tide in opposite directions, scouring alternately north and south, and so depositing, when the tide is ebbing, what it took away when flowing. Thus, there might be said to be a fixed accumulation of sand, gravel, stones, etc., in the immediate neighbourhood of the abutment, brought about by a neutralising tide action. It might be interesting to note here also what a marvellous

strength and binding power there was in strong, thickly-growing sea-weed, secured to rubble work exposed to rapid currents, as was the case along the projecting toes or berme offsets to these viaducts. Then again, in bays and places situated such as Scarborough, Tynemouth and other districts, the huge promontories of land forming the external points of such coast indentations were natural groynes on a very large scale. Very often, too, the erection of long piers and harbours of refuge, as at the mouth of the Tyne, formed artificial groynes on an enormous scale, and collected masses of material which protected the adjoining coast-line. He attributed the safety of the Castle cliff at Tynemouth, and the foreshore at South Shields, largely to the erection of the north and south piers respectively at the mouth of the river Tyne.

Engineers were much more familiar with the destructive than with the constructive action of the sea, but the former action could be greatly minimised by judicious construction in other directions, and for certain purposes. For instance, near Westport, some years back, a concrete sea wall with a smooth vertical face was built to prevent sea encroachment upon a public road. It was found that waves striking this smooth surface at certain stages of the tide, fell down heavily on the base of the wall at strand level, and undermined it. Now walls built in similar positions, but having a rough rubble masonry sea-face, and stepped in front, prevented such a pounding action of the falling waves, and thus the walls were kept from rapid destruction.

Mr. Winn dwelt much, and rightly so, on the very divergent opinions of leading engineers, both as regards the movements of heavy material in deep water, and the disposition of heavy and light materials relatively. The following explanation of the positions of large and small

materials, with reference to their sources of origin, was suggested. Admiral Spratt experimented with a very small number of pieces of clinkers, in comparison with what actually occurs in nature travelling along a sea bottom. It seemed to him that in this case (which is an experiment on a small scale), the pieces of clinkers being few, were, when deposited, considerably separated apart, and a current of a given strength acting upon them in any direction would naturally carry them onwards, more quickly the lighter the objects, which probably become more lifted from an under-pressure of the current. Theoretically, of course, the pressure per square inch on the area of these objects at right angles to the flow would be the same, but the under friction would be greater in the case of the larger objects, and also the mass to be moved, and consequently the weight, would be greater. Now, if they have different conditions, for instance large masses of small beach stones closely packed, it seems quite probable that they are more likely to be held together by a sort of natural bond or space-interlocking, whereas larger stones in their midst would by themselves be more exposed to current action, and would move over and roll upon the floor formed of smaller stones. This would be the case at Chesil Bank, as described by Sir A. Geikie and Sir Charles Lyell. There would appear to be, on reasoning thus, no fixed dispositions relatively of large and small stones—their places would depend on conditions such as are above suggested.

The larger question of establishing some proper system of inspection and protection of our diminishing coast-line is one of enormous importance. It seemed to him that the Ordnance Survey Department should have a branch of its staff set aside for the purpose of recording, by means of sections and levels, alterations in foreshores. He would

make it imperative on County Councils or some similar local bodies to carry out any reasonable works recommended by the above-named Government Department, based, of course, on their detailed records. His observations had transgressed the limits which he had originally fixed, but the subject is a fascinating one to the Civil Engineer, and this was his excuse.

Messrs. Case & Gray, of Westminster, wrote:—

Whilst appreciating fully the object of the author's paper, and the excellent description of certain typical works designed by their late partner, Mr. Case, and themselves, they were compelled to express an emphatic dissent from the author's statements with reference to his suggested curved slanting groynes. The principle of slanting groynes was enunciated as far back as 1848 by Mr. John Thornhill Harrison, M.I.C.E.* The author appeared to take such groynes, give them a curved inclination, and to suggest that in that form they would be a useful auxiliary to the groynes constructed on the Case system. Their experience of groynes was a wide one, gained on a variety of shores in the United Kingdom and elsewhere. They had constructed groynes amounting together to a length of over 20 miles, and had kept systematic record of the changes of the shore level. They had learnt that no obstacle should be offered to the breaking wave as it approaches high water mark. Their groynes commenced at mean sea level, or thereabouts, and extended seawards; they raised the shore level both from low water mark to mean sea level and from mean sea level to the top of the full, and produced the inclination of repose which appertained to every shore after a storm. Accumulation above mean sea level was the inevitable result of the increased height, or improvement in profile below

* Min. Proc. Inst. C. E., Vol. VII.

that level, wherever Case groynes were adopted. Any groynes added to the Case groynes in the region of high water mark were not only unnecessary, but were detrimental to the natural action of the sea in building up the shore. Walls or breastworks were necessary in cases where valuable property was in imminent danger, or where the adjoining land was low and allowed the shore material to be washed inland. Such works should be designed so as not to cause recoil of the waves, and have no projection from their general line, because such projections always cause scour. Structures of this design are the only kind permissible at high water mark; groynes are not. The former are barriers against which the sea can throw up a natural and permanent full; the latter (at high water mark) hinder the sea in so doing, and cause instability. In conclusion, they would quote from a paper by the late Mr. Case, read before the British Association in 1899:—"The author is convinced that it is useless to erect groynes near high water mark for the purpose of trapping beach. Under favourable conditions the beach will accumulate, and will continue to do so for some years, but almost invariably only on the windward side of the groyne. One gale dead on shore, with a very high tide will sweep it away. Unless a foreshore be built up to its true elliptical inclination there can be no stability."

Mr. J. P. Griffith said although he had not been engaged in constructing groynes, yet he had a certain amount of experience of the destructive power of the sea, which the groynes of the author were intended to neutralise. The author had headed his paper "The Constructive Power of the Sea." Of course this was true in a sense, but most of them were more familiar with the destructive power of the sea. He understood that it was the author's idea to utilise these great sources of power in nature for the use

and convenience of man. What struck him most about the Case groynes was their simplicity. In no branch of engineering was simplicity more essential than when they came to deal with marine questions. As the author very properly pointed out, most of this work was of a tentative character. He had seen structures in the form of high groynes, constructed at great expense, which had proved not only injurious to the neighbourhood, but finally resolved themselves into breakwaters, which were undercut by their own action, by their own effect on the waves, and, instead of facilitating or preventing damage they rather brought it about.

The simplicity of the Case groyne was useful, as it gave an opportunity of modifying the groyne to suit the special requirements of any particular locality. They might, for instance, find that the accumulations did not take place on the lines or slopes they had anticipated, and it might possibly be necessary to modify the slope of the groyne, and these alterations could be made without very much expense. He thought the author's suggestion as to slanting groynes was a good one. He understood them to be auxiliaries, and so far as he could follow they appeared to be laid down on judicious lines. The directions of these extensions must be guided by observations on the direction of the prevailing winds, the supply of gravel, etc. He thought the extension of the groyne upwards was a valuable addition to the Case groyne, but he could quite understand that the Case groyne had been very successful without this extension. He regretted very much that they had not an opportunity of again seeing the slides which the author had exhibited on a previous occasion, because nothing, to his mind, conveyed facts so conclusively as photographs. The photographs which the author had shown to illustrate his paper were so interesting that he

hoped the Council of the Institution would publish them in the Transactions, as they would greatly add to the value of the paper. There was a portion of the paper which came home to him with considerable force, and that was where the author spoke of the whimsical action of the sea. Probably many of them had remarked some of these whimsical actions. Accumulation might occasionally go on for years until it raised up a great bank, then suddenly the whole action was reversed, and the sea proceeded to cut away these accumulations until they all disappeared. The author was to be congratulated on the manner in which he devoted himself to solving one particular problem with which engineers engaged in marine work had to deal. It was very refreshing to meet an engineer enthusiastic on any one particular point, and determined to work it out thoroughly.

In Dublin Bay there are two walls stretching out into the sea. On the southern side they had a wall 3¼ miles long from Ringsend to Poolbeg, and another on the northern side, running out to Dollymount, about 1¼ miles long. These walls were built in the 18th and 19th centuries, and their object was to resist the encroachment of the sand into Dublin River—Dublin Bay was a sand trap. A good deal of the sand from the southern shores was deposited in Dublin Bay. This accumulation was one of the most difficult problems which those engaged in the Port of Dublin had to face. Inside these two walls the strands were being lowered, while outside the walls great accumulations of sand had been formed. Anyone who walked down below the Pigeon House ten or fifteen years ago would have seen the shooting range of the War Office on what was known as the "White Bank." This bank began to form about the year 1770, and gradually increased until 1875. It grew to such an extent that it became a

sand dune extending above high water mark, and was a perfect nuisance to the Port—the sand during high southerly winds being blown into the harbour. Since 1875 the sea has cut out this bank. At first the War Office fought hard to retain it, because it was useful as a shooting range, and the high bank prevented the bullets going into the Bay. The bank is now disappearing gradually. The sea has cut through it in several places. He thought this could be given as an instance of the whimsical action of the sea.

In Belgium they had not adopted the Case groynes, but they had adopted low groynes, and in many cases had used concrete groynes. They were something similar in principle to the Case groynes.

He was particularly interested in the author's reference to Professor Engel's experiments. He had a great belief in investigation by experiment where it could be carried out. A great deal of good had been done in that way.

In the preliminary Parliamentary struggles connected with the Manchester Ship Canal large models were constructed to prove the detriment this canal would be to the Mersey estuary. Mr. Vernon Harcourt had studied the question very carefully, and had written a great deal about it. Anyone who was interested in the investigation of these problems would find much useful information on the subject in Mr. Harcourt's writings.

Some years ago he was consulted about the improvement of the approach to the Port of Dundalk. The problem was an extremely difficult one, and there was very little money available. He constructed a model of Dundalk Bay, and the experiments carried out with the model were extremely interesting. He did not know whether any of them had been in Dundalk Harbour, but he might say that its approach channel was bounded by walls which had

been carried a considerable distance out into the Bay. They were practically parallel groynes, with a channel between them, and he was sorry to say they had proved very injurious to the best interests of the Port. He made a model of the Bay, and showed the varied effects of the ebb and flow of the tide through this restricted channel and over the sand bank adjoining. It was found that the results which were shown on this small scale were verified in the fullest manner in nature.

Professor James Thompson also pursued the same course, and introduced experimental models to determine the effects of the flow of currents in the beds of rivers. In the course of his investigation he demonstrated the results produced at river bends by these transverse currents.

There was a remark in the paper which brought this problem to his mind, and that was where the author referred to the bank at Glenbeigh being undercut. In all probability transverse currents similar to those discovered by Professor James Thompson had something to do with this action, but as he did not know much about the district he could not speak with authority on the subject.

Mr. Alfred D. Price said he had much pleasure in seconding the vote of thanks to Mr. Allanson-Winn for his most instructive paper. He was sure that he voiced the unanimous feeling of the Institution when he congratulated the author upon the success which has so far attended his efforts, and also upon the most interesting manner in which he has recorded that success.

From an intimate knowledge of several of the localities where the Case groynes have been adopted, and having had the pleasure of conversing with the late Mr. Case and the author when at Glenbeigh, he was in a position to testify to the value of the system.

At Glenbeigh, or rather Rossbeigh, as the Strand is

more correctly named, there is a strand of about 6 miles in length, exposed to the Atlantic roll from the South West. About mid-way in this strand is the estuary of the combined waters of the Rivers Maine, Laune, Caragh, and Behy, with their wide tidal debouchements. The volume of water in this estuary varies from day to day according to tides, winds, and rainfall, and when it reaches the sea it is whirled into varying currents, at one time along shore, and then setting seawards, forming sandbanks so varying in their position and extent that no chart could correctly indicate them from month to month.

A visitor to this strand will observe the peat formation stretching far out, nearly to low water mark. The problem presents itself how has this peat been formed under sea-level? Has there been a subsidence of the underlying strata? or is the peat the remains of the bed of a fresh water lagoon which was at one time shut off from the tide by a barrier? The evidence seems to favour this latter solution, but the probability is that to both circumstances the position of the peat is to be attributed. He had seen the slanting groynes referred to, which were constructed at Rossbeigh by the author, and he could corroborate the author's remarks as to their retaining the shingle. The Case groynes were only in course of construction at the time of his last visit.

The "Constructive Power of the Sea" was a very expressive title for the paper. The aim of all properly-conceived marine protective works must be to form a natural barrier by, as it were, training the sea to deposit the material, shingle and sand, which is in a state of motion in its waves and currents. Rossbeigh in Kerry is a typical strand for testing the efficiency of such works.

At Youghal the conditions were somewhat different. Former attempts had been made to protect the toe of Clay

Castle by massive walls, but these walls had been levelled owing to the foundations having being undercut by the action of the heavy surf.

The Case groynes had now been adopted, and a large extent of the sea face successfully protected, the power of the sea being changed from that of a destructive to a constructive agent.

The coast to the north of Bray Harbour is composed of perpendicular clay cliffs, which are exposed to easterly and south-easterly winds. The sea there is not like the Atlantic roll, but is of a short, choppy nature, with a strong long-shore current in a southerly direction, removing the gravel and *débris* from the toe of the cliff, and thus making room for each succeeding tide to encroach further inland. Besides this natural waste of the material which protects the coast-line, there is what we may term the artificial waste. Man, in his blind greed, is removing this material; a continual stream of carts may be seen taking it away; and until such depredations are put a stop to, it seems to be senseless to expect that groynes will retain the material. The author claimed a very practical and valuable advantage in this system of low groynes—namely, its property of making sea-beaches. The chief attraction of the most popular seaside resorts is their beach, and in some places injury had been done to the beach either resulting from natural causes or from the erection thereon of high groynes forming unsightly obstructions. So that if seaside places which are without natural beaches can acquire this attraction, and places possessing it already can secure its continuance, the Case system of groynes is indeed a boon and blessing.

Mr. Cowan said he had some experience in building groynes on the coast of Co. Down, where the sea had made considerable encroachments. When he began the works they

were most adversely criticised, and it was stated the money might have been properly spent in piling along the edge of the land but was certainly wasted in the erection of structures at right angles to the coast line. However, when, after some time, the groynes were found to lead to a building up of the beach their value was generally admitted, and the adverse criticism ceased.

He was quite sure the Case system was based on scientific principles, and it appeared to crystallize the whole of the ideas on the subject as to which, until lately, little was definitely known.

The paper would be very useful to any of the members who might be called upon to construct such works, and they were all much indebted to the author for the very able and exhaustive manner in which he had brought the subject before them.

Mr. Winn, in reply, said he would like to say a few words about the communication from Messrs. Case and Gray. He was very sorry that there should be even the slightest difference of opinion between them on the subject.

As a matter of fact, there did not seem to be a difference of opinion. They were both against high groynes, except under certain conditions, such as where there was not sufficient money to build breast-work walls.

His idea was to run a slanting groyne where they had not enough money to build a breast-work wall, and it would be better to have the slanting groyne than not to have anything at all. There were a great many places where they had a long line of coast to protect, and where the shingle or sand is not retained, but carried away, it was very important to get hold of this shingle, and the slanting groynes running down will have the effect of catching and holding this material on the lee side, where it is wanted.

This was shown in Glenbeigh, where for the last two years and six months the shingle has been kept at the back of these slanting groynes. The groynes at Glenbeigh were very rough and ready, and if a good result could be got by groynes of such inferior construction, how much more could be done if they had groynes of more scientific construction?

[6th February, 1901.]

MR. J. H. RYAN, Vice-president, in the Chair.

The message from the King, in reply to the telegram of condolence with him and the Royal Family on the death of Her Majesty Queen Victoria, sent him by the President and Hon. Secretary on behalf of the Institution, was read as follows:—

HOME OFFICE, WHITEHALL,
30*th January*, 1901.

SIR,—I am commanded by the King to convey to the President, Council, and Members of the Institution of Civil Engineers of Ireland His Majesty's thanks for their expression of condolence, which I have had the honour to lay before him.

I am, Sir,
Your obedient servant,
(Signed) CHAS. T. RITCHIE.

M. Backhouse, Esq., Hon. Sec.,
Institution of Civil Engineers of Ireland,
35 Dawson-street, Dublin.

The Council intimated that they had transferred MR. MARMADUKE PURCELL from the class of Associates to the class of Members.

Mr. Walter Elsworthy, was balloted for, and duly elected a Member.

The discussion on Mr. Allanson-Winn's paper, "The Constructive Power of the Sea," read at last meeting, occupied the evening. See pages 165-185.

[3rd April, 1901.]

MR. EDWARD GLOVER, President, in the Chair.

The following candidates were balloted for, and duly elected:—

MR. PATRICK F. O'SULLIVAN, as Associate Member, and Mr. HENRY F. CLAYTON, as Associate.

THE UTILISATION OF SEWAGE.

By MARMADUKE F. PURCELL, Member.

THE problem besetting every engineer dealing with sewage drainage, is how, when he has collected the sewage, he is going to get rid of the solids contained therein? This is comparatively an easy matter in the case of small towns situated on the seashore, but becomes more perplexing in accordance with the increased size of the town or city which has to be dealt with, as, in the case of large deposits being sent out with the tide, there is always the danger, almost the certainty, of such deposits being swept back to a large extent, and re-deposited on the foreshore, there to become a nuisance and a danger, to say nothing of being a waste of valuable material. Then, as we go further inland the problem becomes more pressing, for you must either pollute your rivers, again losing matter of value, or you must treat it as a manure, and sell the sludge or cake to the farmers, or else utilise it on sewerage farms. Both these latter alternatives have their respective values, and also their striking disadvantages; in the former case the value of the sludge to the farmer depends largely upon the form of precipitant employed at the settling tanks; and even then, if suitable for their particular crops, they object to sending their horses and carts to draw with each load more water

than manure; and again, owing to presence of such precipitation material as is most usually employed in the tanks, the full decomposition of the constituents of the sludge is delayed after being spread over the land, and as a consequence the best results are not obtained for the farmer as speedily as he can obtain them from artificial or natural manures. The question of sewerage farms is one which I do not feel myself competent to enter into, but I understand that to be effective the area must be great, so as to get the acme of efficiency, and the sludge should be dug in, and the ground left fallow for three years to obtain the best results; consequently, in any up-to-date sewerage farm, you could only have one-third of it under cultivation at any one period; but, there is a much graver aspect of the sewerage farm system, and that is, the indestructibility of disease germs by the ordinary methods of precipitation employed at depositing stations, and the absorption of such germs into the cellular tissues of the vegetables grown on such farms, and their transference in the course of their use to the human body, and the resultant spread of such diseases as Typhoid, &c. This alone should lead us to do all we could to utilise in some other way the valuable asset that every community produces, which many throw away, others misapply, and all would like to recover. But the question is, how to do this efficiently and economically; how to produce value where at present we have loss and danger. These were the questions that presented themselves to my mind some years ago, and to which I endeavoured to get a satisfactory answer. I knew that many workers before me had gone into the same field, and retired, baffled and disheartened. In the course of my investigations I came to the conclusion that in place of looking for and dealing with a single resultant of the quartette that may be derived from the sludge deposit, the

only thing for an economical working would be to obtain all four (main) products, and that, if possible, at a single operation. Leaving out my earlier efforts I will endeavour to give a succinct account of my ideas and experiments dealing with the deposit from the time it is filter-pressed and delivered at the works.

My object is the distillation of the filter-pressed-sewage obtained from any sewage disposal works where the use of filter-presses is adopted, and, assuming the cakes of sewage can be obtained first hand, and in such a condition as to bear transit, then the process has for its ultimate object the production of oil, ammonia (as ammonia-water), and a solid residue which is to be converted into cement—for which purpose it is admirably fitted, especially where lime has been used as a precipitant in the separation of the sewage into sludge and effluent, as is the case in London.

The London "sludge" contains:—

Moisture	58·06	Nitrogen calculated as Amm. Sulphate ·87 per cent. Wet Cake.
Organic Matter	16·69	
Mineral Matter	25·25	

The Mineral Matter contains:—

Carbonate of Lime	7·94
Free Lime	2·45
Silica	8·08
Oxide of Iron	·97
Alumina	3·39
Phosphoric Acid	·65

From mere inspection of the above results it will be seen at once that by simple drying of the sludge it would give a body capable on distillation of yielding very large amounts of ammonia, and also an oil, which would be of value as a carburetting material in the manufacture of gas. Experiments were first made on a small scale in the

laboratory with pressed sludge obtained in London, and very promising results were obtained; then an ordinary gas retort was tried, with inferior results both as regards the yield of oil and ammonia, and it was also conclusively shown that the vertical position of the retort was the proper one if the largest yield was to be obtained, and also the sewage must be distilled in a retort capable of giving two different temperatures (or preferably four), one (the lower) at which the elements present in the material chemically combined to form the oil vapour, and another at which the Nitrogen (still present as such in the spent shale) was burned, so to speak, in an atmosphere of steam and converted into ammonia by the aid of the caustic lime produced in the operation. With these facts in view a small experimental retort was set up at Barking and tried by producer gas—and from this small and very imperfect apparatus considerable experience was obtained and oil and ammonia sulphate produced. It was shown that *external* heating of the retort was of no value if a high percentage of ammonia was to be obtained, and therefore a retort on the principle of the Young and Bilbey is the most suitable for the purpose. The oil obtained from the sewage would be of value for either burning or converting into gas. The residue coming from the retort was a valuable body, and could be converted into a very fair cement worth at least 10s. per ton. A very large proportion of incondensable gas was produced during the distillation which could either be turned into the retort benches or used as fuel to dry the cakes of sludge before they were distilled. The method of distillation to be adopted would be on very much the same plan as that used in Scotch Shale works, except that before the sewage could be distilled it must be dried, and this would be done by the waste gases arising from the retorts, and by carrying the

hot gas flues under floors on which the cakes of sewage were placed. With this exception the process would be identical with the Shale distillation, oil, gas, and ammonia water being produced and condensed in suitable receivers, and afterwards separated, and the ammonia obtained in the form of sulphate, and the great factor in the profitable production of oil from Shale is the number of pounds of sulphate which is obtainable from the ton distilled. This in Scotland may be taken as between 25 and 37 lbs. per ton (the highest average).

Appended is a copy of the Balance Sheet of an Oil Works using Henderson's Retorts, and from that the following figures have been obtained:—

1. The yield of crude oil per ton of shale is about 37 gallons.
2. The yield of ammonia sulphate is about 18 lbs.
3. The cost of mining and obtaining the shale is 4s.
4. The cost of distilling and producing the oil is 4s. per ton of shale.
5. That by far the largest profit in the manufacture is obtained from the production of the ammonia sulphate.

Now it is evident that if the compressed sewage can be obtained from the sewage works for the simple cost of transit, or at a nominal cost, or utilised by the authorities on the spot, and that by distillation it can be made to yield a high percentage of ammonia, and also give oil, and a valuable residue in the form of a cement, then a very valuable return will be made by treating such material.

From the results of a great number of experiments made, both in the laboratory and on a larger scale, it has been proved that on the average about 9 to 10 gallons of oil would be obtained, and from 57 to 65 lbs, of sulphate of ammonia; in some cases over 100 lbs. to the ton was obtained.

The following are the results:—

Wet Cake from	Ammonia Sulphate	Residue	Oil per ton	Water
Cross Ness -	57·56 lbs. per ton	39·00 %	7 to 11 galls.	54·10
Leyton -	59·80 ,, ,,	68·40 %	9 to 10 ,,	52·00
Wimbledon -	65·63 ,, ,,	56·00 %	5 ,,	51·00

In carrying out these experiments I found that it is necessary that the cake should be nearly dry (not containing more than 15 per cent. of water), before it enters the retort, and for this purpose the waste heat from the retorts would be economised, and also the gas evolved during the distillation; even if extraneous heat had to be applied the cost thereof would not equal the cost of mining the shale, which amounts to four shillings per ton, and therefore, if we obtain from the sewage products which are as valuable as those obtained from the ton of shale, the process still remains on a remunerative basis.

The oil obtained is neither so large in quantity or so good in quality as crude shale oil, and would not be worth more than 1½d. per gallon, for carburetting purposes, but the yield of ammonia would be nearly double that obtained from shale, whilst the residue when ground would certainly be valuable as a cheap cement and quite good for the purpose of making concrete.

The yield of one ton of sewage cake containing say 15 per cent. of water would be roughly as follows:—

		s.	d.
20 gallons crude oil at 1½d. per gallon	...	2	6
80 lbs. ammonia sulphate, 1½d.	...	10	0
10 cwt. of residue suitable for cement	...	5	0
		17	6

The cost of obtaining the above would approximately be as follows:—

	s.	d.
Drying 2 tons of sewage cake, say 2s. per ton for coal used in addition to the waste heat derived from retorts	4	0
Cost of distilling and producing the crude oil and ammonia	4	6
Cost of crystallizing the sulphate of ammonia, and cost of sulphuric acid necessary	2	6
	11	0

The amount of ammonia is taken at much less than that really obtained from the process, even when working with a very imperfect apparatus, and the value of the residue is certainly taken at a very low figure. The proper method of really testing the process would be to erect a bench of say 10 Young and Bilbey's retorts, capable of passing about 30 cwts. or 2 tons of shale in 24 hours each. With sewage very possibly a little more might be got through.

The cost of these may be taken at from £55 to £65 each, and there is no doubt that by the use of these retorts that a much higher yield of ammonia would be obtained.

Following up my own experiments I had a consignment of pressed cake sent from Glasgow to a large Shale Oil Works, where by the courtesy of the heads of the works they carried out a distillation for some of the pressed-cake in their experimental works with most satisfactory results, as you can see from the return they certified to me from their tests. The results they got were as follow, from the cake as received:—

Moisture	71·335
Organic Matter	10·210
Ash	18·455
	100·000

On distillation in experimental retort, in presence of steam, the following yields were obtained:—

	Original Sample.	Dried Sample
Oil (lbs. per ton)	11·779	41·094
Sulphate of Ammonia (free) (lbs. per ton)	19·884	69·367
Total (lbs. per ton)	24·486	85·421

It will be observed these figures are not mine, but those from a flourishing industry which makes the greater portion of their money out of the sulphate of ammonia produced; and in their experiments in an unsuitable retort, adapted for the distillation of shale, they succeeded in getting some fifty pounds of sulphate of ammonia per ton more out of the sewage contents than with shale; this does not take any account of either the gas, some 4,000 cubic feet per ton of cake, produced, nor yet the oil or the residue of the combustion which properly treated in the retort yields a valuable resultant in the form of the cement. In dealing with the sewage on a large scale, I should propose that the retorts be set up in benches in a manner similar to a shale works, only differing slightly in construction to allow of the spent residue being drawn from time to time, the gas could be used for firing the fresh charges, and also the boilers necessary to produce steam for injection into the retorts, for the purpose of procuring the largest yield of ammonia. The oil is so small in quantity and so valueless in price that its principal use would be for carburetting a certain proportion of the produced gas for the purpose of illuminating the works.

The few words I have said are not put forward other than as a record of experiments carried out with a fair amount of success, and now offered with a view of getting the opinions of those more able than the author, and to draw attention to a most valuable matter for utilisation, and which at present is either a danger and a nuisance, or rown away.

APPENDIX.

Cost of Distilling one Ton of Shale, and Products derived therefrom.

	£	s.	d.
To total cost of getting 69,808 tons of Shale equal to 4s. per ton	13,994	0	0
,, Sulphuric Acid required equal to 6s. 5d. per ton	1,945	0	0
,, Coal, 1s. 3d. per ton	4,403	0	0
,, General Repairs, 4s. 5d. per ton ...	1,394	0	0
,, Wages, 1s. 8d. per ton	5,906	0	0
,, Expenditure on horse labour, &c., expenses, commission to managers and clerks, salaries, &c. Taxes and surface damages, 4s. 5d. per ton	1,242	0	0
8s. 2½d. per ton ...	£28,884	0	0

	£	s.	d.
By Price of 2,555,680 galls. of Oil produced from 69,808 tons of Shale (or 36·60 gallons per ton)	28,842	0	0
,, Price of 11,179 cwts. of Ammonia Sulphate, 13s. 11d. per cwt.	7,801	0	0
,, Price of 80,661 galls. Naphtha	458	0	0
	£37,101	0	0

The profit derived under each head may be held to be as follows:—

	Prices received	Cost	Profit
Oil	£28,843	£25,268	£3,576
Ammonia Sulphate	7,801	3,188	4,612
Naphtha ...	458	311	146

EXPLANATION OF PLATE X.

A—Retort.
B—Double cover of same.
C—Pipe carrying products to,
D—Washing and oil tank.
E—Ammoniated water.
F—Oil.
G—Pipe conveying gas to,
H—Gasometer.
K, *K*—Syphons to carry over the oil and ammonia water to separate reservoirs.
L—Chamber to remove cement from retort.
M—Tip waggon for conveying cake to retort.

Mr. James Dillon said they were very much obliged to the author for having taken the trouble of bringing this subject before the Institution. If the paper and the figures put forward were found to be accurate it would be a matter of the greatest importance to engineers. If it was found to be a successful way of dealing with sewage sludge it would alter the whole character and reduce the cost of sewage works, inasmuch as if they could use the sludge profitably then they would be able to do away with all those costly works which they have had to adopt in order to try, even at a loss, to get rid of the sludge to consumers for the cultivation of their lands. He had visited a large number of sewage farms in different parts of England, and in most of them, whether large or small, he found they had great difficulty in getting rid of the sludge. In the Birmingham sewage farms they had kept on adding to the farms, and still had not enough land, and they were now taking steps to adopt some other system of dealing with the sludge. They had found the quantity of sludge was so great that if all used it would injuriously

affect the productive powers of the land, and there were other objections in addition to the great cost.

Manchester was in the same way. They had tried different methods from time to time, and spent enormous sums of money, and they had become disheartened at the results. They were now considering the septic treatment, but the Local Government Board (in England) were not quite satisfied with this method, unless largely aided by land filtration to preserve the river waters from sewage pollution, thus adding considerably to the enormous cost of works of this description.

If the methods mentioned by the author were adopted it would help them very considerably out of their difficulty.

Coming nearer home, to their own city, the Corporation were now expending enormous sums of money in building a main drainage system, and they intended to bring the sewage down to somewhere near the Pigeon House, where it would be delivered into tanks, to be pumped from them into ships and brought out to the sea. These tanks would have to be very large and costly, and they would have to be emptied at all times of the year. This would be very expensive and troublesome, especially during the winter, requiring powerful steamboats or tanks. Other towns had tried different methods of delivering sewage into the sea, and where there was a tidal current flowing in the right direction out to sea and away from the shore it had turned out a great success. But if the facts and methods mentioned by the author were correct we were undoubtedly delivering a certain amount of gold into the sea from whence it could not be recovered. He thought the Corporation ought to give a trial to the methods referred to in the paper with a view to see if they could not reduce the enormous cost of dealing with the

sewage in the way originally intended for the City of Dublin and the surrounding districts.

SIR CHARLES CAMERON said the subject which the author had brought before the Institution was at all events to be regarded as a very important one. Quite apart from the particular scheme for disposing of sludge which the author had dealt with, they knew it was a matter of great importance to be able to deal economically with immense quantities of semi-solid matter which were produced in the case of treatment by precipitation or subsidence of the sewage of a large city like Dublin with its 300,000 people. There was no doubt when the sludge which was produced had to be conveyed out to sea there was no return value whatever from the labour bestowed upon the disposal of the sludge. The country was not enriched by the production of any one article. They had no material for making cement. They had no material for the manuring of their fields. But if they treated the sludge in such a way as suggested in the paper they would get something out of it which would be of value. There might be an increase of expenditure in comparison to the cost of bringing it out to sea, but still there would be the gain to the country, for they would have something to put into their fields, and something to use in their industries.

He thought that was the idea that the author had in taking up this question. The matter became more important in the case of inland towns. He had always held in the case of Dublin all they had to do was to send a clear liquid out into the Bay, no matter how much dissolved organic matter it might contain. But that was not the case in dealing with such large towns as Birmingham, where the sewage should be properly treated so as to convert it into liquid without having a large

quantity of dissolved matter which would very often prove offensive by undergoing secondary fermentation. In dealing with this question, whether in towns on the sea coast or in inland towns, there would be large quantities of matter precipitated, and the author had said a great deal with regard to the proper way of treating that sludge. There was a great disadvantage in carrying it out to the sea. Anyone who had made a voyage on the Corporation barge "Eblana" would tell them how unpleasant it was. They had the same unpleasantness in Liverpool with their barges. There was a proposal that the sludge should be used for reclaiming the foreshores along the south side of the Pigeon House wall. That part of the foreshore is anything but salubrious. He was inclined to think there was a good deal in the paper, but he was not going to say the calculations would work out in actual practice; but he thought it would be worth while to give a trial to the process. It was not necessary that a great expenditure should be incurred in doing so. They did not require any large expensive plant for testing whether this was an economical process or not. He thought it would be worth while in the case of Dublin to see what products could be obtained per ton of sludge, and to see whether it would be more economical to adopt the author's proposals than to convey the sludge out to sea. With regard to the sulphate of ammonia, he thought the author had not exaggerated the value of the ammonia produced. At the present time it would be worth more like 6d. per lb. He agreed with the author that the value of the oil produced would not be very much. He considered it could only be used to burn in the furnace. The really substantial product would be the ammonia. They had to consider whether the sulphuric acid would be purchased. A large portion of the profit in making artificial manures was derived from the manufac-

ture of the sulphuric acid, and if the sludge manufacture was on a large scale it would be desirable to have the sulphuric acid manufactured, but if that was not convenient the sulphuric acid could be purchased.

The subject of the paper was a very important one, and it would be of great importance to Dublin in a couple of years. He had calculated that the amount of human excreta of the city annually was equivalent to a value of about £93,000. Of course it would be impossible to get so much money out of it, but if they could get 10 per cent. it would be a matter of great importance.

Mr. W. J. Haslam said he would like to know more about the cement mentioned by the author. Could he give them any analysis of the residue coming from the retort showing the percentage of alumina, and whether it was really valuable as a material for producing cement. Sir Charles Cameron had stated that the oil produced was practically worthless, and he did not see anything in the paper to show whether the residue was a suitable ingredient for the making of good cement. Then, supposing the cement was worth nothing like the oil, it would reduce the value of the product to 10s, whereas that same product would cost 11s. to produce. Unfortunately there were not many large towns in this country, and any they had were on the sea coast, where the sewage could be dealt with in other ways.

The President said they all ought to be very thankful to the author for bringing this paper before them. A short time ago they had a paper on the "Disposal of Sewage." Everything connected with the question was both difficult and important, inasmuch as it affected the lives and pockets of the community. In this particular paper they had the utilisation of the sewage, which, in other words, means first the production of sludge, then

the utilisation of the sludge. As has been said, all their towns were not large towns, and their greatest difficulty in some places was to make the sludge. In considering questions of this kind it was well to remember that the spending of large sums of money was an advantage, even though the returns were not very much in excess of the outlay.

As regards the cement, the author had not stated the results of his experience of this cement in concrete. Of course its value would depend upon the proportion of sand or gravel used in the manufacture of the concrete. It was also important to know what were its setting properties. The paper was so entirely chemical that he did not feel himself competent to say very much upon it.

Mr. Purcell, in reply, said he had seen the effects of the Manchester sewage farms, also of the Cambridge sewage system, where the River Cam had been destroyed, not a fish being left alive in the river, and the sewage (and consequent germs of disease) were floating about on every side. He had got some samples of the vegetables that had been grown on sewage farms, and had analysed them. In a number of them he had found disease germs that had been absorbed by, or into, the cellular tissue. With reference to the Corporation barges, and the non-return of the deposited refuse and sewage, he could only say that when he was a youngster he used to sail round Howth, and on the far side he could point out where he was able then to get six fathoms of water, and now he would not dare to sail over that part owing to the material which had been carried in there by the current, and which had come from the Corporation barges dumping at sea. With regard to Sir Charles Cameron's suggestion about depositing the sludge on the foreshore, or south wall of the Pigeon House, he did not think that would be a good plan, for the effect of

the wind, sun and rain on it would not make it more pleasant than it was at present, and, indeed, under their combined influence might eventuate in a grave danger to the City of Dublin. With reference to the cement and concrete, he had tried it himself, and also had got it tried by Professor Butterfield, F.I.C., F.C.S., with very satisfactory results. In making concrete with the residual cement they could get a very good concrete with about 50 per cent. of sand. They could also use it in the proportion of 1 to 5, and they would find this very profitable.

[1st May, 1901.]

MR. EDWARD GLOVER, President, in the Chair.

The following candidates were balloted for, and duly elected, viz.:—

Mr. HENRY BEVAN SLATOR MONTGOMERY as Member, and Messrs. HENRY NORMAN LEASK and FRANK V. JOHNSON TRAVERS as Associate Members.

THE GALWAY AND CLIFDEN RAILWAY.

By J. H. RYAN, Vice-President.

AMONG the several railways projected under the Light Railways (Ireland) Act of 1889, the Galway and Clifden line is the longest and most important. The railway traverses that part of the West of Ireland situated between Galway Bay on the south, county Mayo on the north, Lough Mask and Lough Corrib on the east, and the Atlantic on the west, known as Connemara, Iar-Connaught, and Joyce's Country. (See Map, Plate XI.) This area is 750 square miles in extent, and with an average population of 68 per square mile, the greater part of whom live along the coast-line, which this railway does not touch except at its termini at Galway and Clifden. The district is mountainous and rugged, and, to quote from Maxwell's Wild Sports of the West of Ireland, "abounds in bogs, lakes, and other natural curiosities; its soil consists of equal quantities of earth and stone, and its surface is so admirably disencumbered of trees, shrubs, hedges and ditches that an intelligent backwoodsman from Louisiana was heard to declare with rapture that it was the most perfectly cultivated territory in Europe." It is a favourite resort of the angler, and its wild and beautiful scenery now being within easy reach, will attract the tourist.

Hotel accommodation until quite recently was a desideratum; steps, however, have been taken by the Midland Great Western Railway Company to rectify this. A short account of the country and scenery along the route of the railway, photographs of which are reproduced, may be of interest.

Leaving Galway, "The City of the Tribes" (styled in ancient Irish writings Dun Gallive, the Doon or fortified place at the mouth of the River Gallive, now called River Corrib), from the station of the Midland Great Western Railway, the line passes through the eastern outskirts of the town and under Prospect Hill by a tunnel, the only one on the railway, described further on. The line thence proceeds over the Corrib River by a bridge, an imposing and elegant structure of steel. A fine view of the town can be obtained from this bridge, as well as of the river. Crossing the bridge, the line traverses for miles the west side of the River Corrib, passing deserted mansions, breweries and factories. On the east side of the river is seen Terryland, or Tir-Oillen, the pass or "Ford of Oillen," the ruined castellated mansion of the De Burgos; and next, Menlo Castle, the picturesque residence of Sir Valentine Blake, Bart., standing on the water's edge; the date of its erection is buried in antiquity. The railway thence traverses the west shore of Lough Corrib, or Orib, which is the second largest sheet of inland fresh water in Ireland; it is about 35 miles in length, and varies in breadth from 8 miles between Cong and Oughterard to a quarter of a mile from Wood of Doon to Curraun Point, where it narrows between the Joyce Country and Iar-Connaught hills, covering 44,000 acres. On the left or western side of the line are seen the range of hills that stretch from Galway to Oughterard. Along their slopes are the well-wooded demesnes of Woodstock, Danesfield, Drimcong, Ross, Kila-

guile, &c., with ruins of mansion, castle, and abbey, and also the village of Moycullen or Magh-Uillin (the plain or field of Uillin), where there is a station of that name, beyond which, and along the line, are seen the picturesque woods, glades, and lakes about Drimcong, and Ross; at the latter is the station of that name and the picturesque and ancient residence of the author of that world-famed song "Ballyhooly."

As the town of Oughterard ("the upper height") is approached, the district presents a more civilised aspect; near it is the pretty fall of the Owenriff River ("the sulphur river"). Leaving Oughterard, the line takes a westerly course. Views can now be had of Carn Seefin, between Oughterard and Doon towards the north, and the bold flat-topped outline of Benlevy. The line now enters the region of Connemara—Conmaicne-Mara—the maritime Conmaicne, or territory of Conmac, a descendant of one of the sons of the celebrated Maev, Queen of Connaught, and Fergus, ex-King of Ulster. Properly speaking, this district is included within the present barony of Ballinahinch, where old "Dick Martin ruled the wilds of Connemara." Next the line passes Glengowla, where lead and copper mining operations were carried on many years ago by the enterprising Mr. Hodgson, of Curraghreevagh; thence on to Maam Cross Road Station, passing on the way the shores of Lough Boffin, Lough Inieraun, Arderry Lake, and Lough Shindilla. From this roads lead south to Screebe, &c., and north through the valley of Maam, pronouncel Mawn—a gap or pass—towards the fjord of the Killeries. From this pass in the mountains at Maam it is said St. Patrick, when on *his* tour, seeing to the south the desolate and uninviting region, took up his abode there for the night, saying, "I'll bless you, any way; but sorra foot I'll ever put upon you."

Before reaching the station and towards the north can be seen the upper portion of Lough Corrib from Maam to Doon, on the placid surface of which stands solitary the ancient Hen's Castle, said to be the oldest fortress of its kind in Ireland, surrounded by rugged mountains overhanging Maam to the north, and ending at the southerly end in the wooded hill or Doon of Castlekirk.

Leaving Maam Cross Station, the line now enters the Joyce Country and Connemara proper, a region perhaps grander, wilder, and more romantic, the mountain slopes changing into grey bare rocks, with varying hues. Lake and river meet the eye at every turn, and the line passes Lough Shindilla, Lough Oorid, and through the valley of the Recess River to Recess Station, at 35½ miles, on Glendalough Lake. To the right of the picture can be traced the railway along the lake shore, and in the distance some of the twelve pins or *Bens* (peaks) of Bunnabola, a remarkable group of mountains. From the station roads lead north, south, east, and west, that to the north by the picturesque shores of Derryclare Lake and Lough Inagh, both studded by wooded islands, and surrounded by lofty mountains; thence to Kylemore, Letterfrack, and the Killeries, and on to Westport; the road south leads to Cashel and Carna. At the former is situated the comfortable Zetland Arms Hotel, so called after Lady Zetland, who visited this wild region when on her mission of charity a few years ago. Leaving Recess, the line passes the southern shores of Derryclare Lake, Athry Lough, and the east end of Ballinahinch Lake, thence by Lough Nabrucka, Ballinafad Lough, and Killeen Lake, from which a view of Benlettery ("wet hill side peak") is taken. We next reach Ballinahinch, at 40¾ miles, which stands at the head of the river of the same name, connecting the lakes with the sea, and famous for its salmon and white trout fishing.

Close to this is Ballinahinch Castle, the picturesque demesne and residence of Mr. Berridge, a popular landlord, and one who has done much to better the condition of the people and the face of the country by judicious planting; the railway runs for upwards of 20 miles through his property, the land for it having been given by him free of cost to the railway company. This was the ancient seat of the Martin family, the avenue to whose castle was said to be 50 miles long.

From the station here Roundstone can be reached, a prosperous town on Roundstone Bay, five miles off, to which, if a branch line were built, some development of the sea fishery might result, a purpose for which the Light Railways Act was conceived. From Ballinahinch westward there is a long stretch of wild and rugged country, interspersed with many lakes, before reaching the terminus at Clifden, situated at the east end of Ardbear Bay. There is a small quay close to the town, but difficult of approach, as also is the bay; so, although there are large fishing banks off the coast, the industry is of little importance.

The total length of the line is 48 miles 550 feet, and it commences by a junction with the Midland Great Western Railway of Ireland system at their Galway station, of which system it is an extension and forms an integral part, of the same gauge (5 feet 3 inches). It is a single line, and for convenience during construction it was divided into three divisions which were respectively in charge of resident engineers.

The first division was opened for traffic on the 1st of January, 1895, and the rest of the line on the 1st of July, the whole being nearly five years in course of construction, a period, it would seem, unnecessarily long, but accounted for to some extent by the company being obliged to take over the works from their first contractor, thereby causing delay.

Mr. Balfour being in office as Chief Secretary for Ireland in the year 1890, and being anxious to improve the condition of the country and the people, for which object the special Act was passed, pressed the Midland Great Western Railway Company to commence work as relief works, a request which was generously responded to by the chairman and directors. A free grant of £264,000 was given to the company by the Government towards the construction of the new line, on the condition that it should be maintained and worked by them. The company accordingly retained the author and Mr. Townsend, C.E., of Galway, as joint engineers to undertake the necessary preliminary work required by the Act for an Order in Council, to lay out the line, prepare the contract plans and estimates, &c., and superintend the work to completion. A very limited time, however, was given to the engineers to prosecute the surveys which the length of the line and the difficult nature of the country through which it passes demanded, and, to add to their difficulties, they had to encounter that of the elements, which were exceptionally severe at that time, causing a serious hindrance. Pending, however, the completion of contract, surveys, plans, &c., a provisional contract was entered into in the winter of 1890, and employment was given to the people. This work was chiefly confined to bog lands; drains were cut and surface formation commenced. This work ceased in the spring of 1891, and tenders were invited and contracts entered into for the completion of the line in two years ending in December, 1893; extra time, however, for completion had to be applied for under Privy Council orders on two occasions.

The general alignment of the railway is excellent, with very gentle curves and easy gradients, the sharpest curves being 10 and 12 chains, which occur near the town of Galway, and 2 furlongs in open country. Where reverse

curves occur, a straight intervening portion of 5 chains was required by the working company; these requirements entailed in some cases heavier work than would otherwise have been necessary. The worst gradient on the line is 1 in 70, of which there is only one; it occurs at Oughterard, at 17 miles, for a length of about 2,300 feet. There is one of 1 in 72, at Recess, at 34¼ miles, 700 feet long; and one of 1 in 73, at Ballinahinch, 1,100 feet long. In general the gradients are easy, the railway following the watersheds draining into Lough Corrib on the east up to its summit at Lough Boffin, 23 miles from Galway, the Screebe fishery watershed between this and Bunscaniff at 28¾, which latter is the summit level of the railway, and the watershed draining into Kilkieran Bay and Ballinahinch lakes, in the mid-distance, and into Clifden on the west, as will be seen by reference to the map.

Throughout the line the slopes of embankments are 1½ to 1, the toes of which are pitched with stone pitching where they abut on the shores of the lakes or banks of rivers; the slopes of cuttings in rock are ¼ to 1. The width of formation in banks is 16 feet, in cuttings 15 feet. In bog lands the land was of a very diverse character, entailing different treatments, the most important step in which, however, was drainage. In some cases, where the surface of the bog was irregular and bogholes occurred, turf sods were cut outside the line of the railway, and the inequalities filled up with them, so as to strengthen as much as possible the natural surface of the bog. Then the material from the side drains, which had become dry, was wheeled on so as to form a cushion, and made thereby a light embankment. In other cases brushwood was laid down on the surface to varying depths, according to the nature of the bog, and the quality of material in the embankments, except in the

case of high banks of rock from adjoining cuttings, under which brushwood would be of little use. Owing to the scarcity of timber and brushwood west of Oughterard to the coast line, its use was very expensive. In the case of the banks made of turf, above mentioned, through bog, the top of the bank was made up, for a depth of from 18 inches to 2 feet, to the formation level, with a layer of the stiff clay or marl which generally underlies the bogs. This was found very efficacious, as when this material dries out it becomes quite hard, and renders the bank firm and solid. Where the above treatments did not suffice and the bog was shallow, clay and rock were tipped in until the bottom was found. In some cases rock only was tipped, being more economical, as clay spread very much below the bog surface. The slopes of the peat banks were cased over with clay to prevent them taking fire.

Side ditches were cut longitudinally on each side of the centre line, and where a double line of ditches occurred, cross-drains connecting them were cut at convenient intervals, generally at every 100 feet, also cross-drains about 25 feet apart from the toes of embankments to the inner longitudinal drain. The cross-section of these ditches had to be continually maintained until consolidation took place, and the experience was that frequent outfalls were necessary to keep the outside drains from closing in and getting choked owing to the bottom bursting up. In some cases, where the line was in cutting in bog overlying hard ground or rock within 3 feet or 4 feet of formation, it was excavated to the hard and refilled with clay. If the depth of peat exceeded 4 feet 18 inches of this was excavated and filled in with clay until a bearing was obtained, which was generally attained when about 3 feet of clay was tipped in, the weight of the sides of the cuttings keeping the clay from spreading. This treatment has answered the pur-

pose very well indeed. In some cases a thin layer of brushwood was put on top of formation.

The nature of the rock excavation from Galway to Oughterard is limestone well bedded, and the best for building purposes was found at Rineen, 10 miles from Galway on the line of railway. This limestone formation is metamorphosed into black marble in the neighbourhood of Oughterard. From Oughterard westward the geological formation varies extensively, and the rock sections exposed by the cuttings have assisted geologists in determining the geological character of rocks, which belong, for the most part, to the schistose series, the origin and age of which have long been involved in doubt; most of the schists are proved to be igneous rocks, which have been altered during successive periods of metamorphism. The principal rock cuttings are, at Oughterard, 16¾ miles, about 700 yds. long, average depth 25 ft., in which is met carboniferous limestone, crushed green quartzite, granite (red and white), hornblende schist, &c. The cutting is traversed by some well-marked fault-planes. Through a considerable part of the cutting the rock is covered with a layer of peat containing numerous tree roots. The cutting north of Lough Shindilla, 27¼ miles, shows chiefly greenish and purplish quartzitic mica schists, and the cutting between Loughs Shindilla and Oorid, 28¾ miles, which is about 12 feet deep, shows crushed quartzitic mica schist with a large vein of normal granite. The cuttings along Lough Oorid show interesting granite intrusions in the schist, and thence, up to Derryneen Bridge, 32¼ miles, most of the cuttings are in hornblende schist with quartzitic bands, while west of this the cuttings are all in quartzitic mica schists. From the neighbourhood of Derryneen an example of folded strata on a large scale may be seen on the side of Letterbreckaun, the most

northerly of the Maam Turk Mountains, about 5½ miles distant.

The rock excavation from Oughterard to Clifden was very hard to get through; blasting powder, where the rock was not wet, giving by far the best results, but tonite and dynamite were largely used, the former being the favourite. (Plate XII., Fig. 1.)

The clay excavation varied from very stiff boulder clay in the neighbourhood of Galway to clay and sand of ordinary nature at Ross, 12 miles, showing gravel at Killaguile, 13 miles.

Beyond Oughterard to Leam the clay is intimately mixed with sand showing fairly good pockets of ballast at places, principally at Leam, 20¾ miles. From this, westward, clay does not occur in bulk by itself, except near Clifden and in a few isolated instances, but is generally always found as a covering to the rock in thicknesses of from 1 foot to 8 feet, interposed between the rock and the peat.

The fencing in bog lands consists of three wires secured to posts driven sloping every 9 feet in the railway side of the outside drain; that in clay lands consists of ditch and mound, surmounted by posts and three wires 2 feet 3 inches high. Where rock occurs close to the surface, dry stone walling 4 feet 9 inches high by 1 foot 9 inches thick was adopted, pointed with lime mortar and coped; also a seven-wire fence 4 feet high was used on a portion of the line near Galway, where the other classes of fencing were not suitable. This consisted of six lines of 7-ply galvanised strand No. 5 W.G. and one of No. 4 W.G., stapled to posts 6 feet apart, and sunk 2 feet 6 inches in ground, with strainers 200 yards apart.

Gatekeepers' houses are erected at public road level crossings, which are 18 in number. They have all the rooms on one floor, and up to and including that at

Oughterard, are built in a superior manner, with squared limestone face joints, having horizontal and vertical random heights, and no spauls showing. The quoins, jambs, and chimneys are of Kingscourt brick. They contain living room 16 feet 6 inches by 12 feet, and two bedrooms, each of 8 feet by 10 feet 3 inches, with fireplaces. There is an outside porch covered by a continuation of the main roof; and out-offices consisting of fuel-house, privy, and ash-pit, are provided. Each house has an English rood of ground attached, and is fenced off from the railway. Beyond Oughterard the masonry of the houses is of ordinary rubble, pebble dashed, the red brick quoins and jambs showing clear of the dashing.

The line is single and the stations form passing places, except at Ross and Ballinahinch. The permanent way consists of steel flange rails 65 lb. to the yard, in 30 feet lengths, with a percentage of shorter lengths, with deep angle fishplates, secured to half-round creosoted cross-sleepers by dog-spikes and four-fang bolts on straight portions, and on curves by five-fang bolts; also check rails are used on all curves under 15 chains radius, and tie-bars. A wrought-iron sole-plate is interposed between each sleeper and the flange of the rail; sleepers average 9 feet by 10 inches by 5 inches, laid 3 feet 1½ inches, centres, except at joints, where they are 1 foot 11 inches apart.

A portion of the permanent way over Munga bog, near Clifden, was laid in similar manner to the main line way of the Midland Great Western Railway, viz., with 79 lb. flange steel rails, as it was found that over boggy land this type is much stiffer and better suited than the lighter section.

The formation in general is pitched with broken stone pitching 6 inches deep, set on edge for 12 feet in width. none, however, was laid on some of the bog banks and

cuttings, as it was found that the stone cut into and became bedded and choked in the clay surfacing. Coarse gravel, with a slight admixture of clay to make it bond, was substituted, and a border of stone was pitched on each side.

The ballast and boxing on the first division is all gravel ballast; and up to the 27th mile it consists of gravel and a small admixture of broken stone; from the 27th to 35th mile broken stone was first laid down and packed under the sleepers, and then the second lift was made with a top dressing of gravel. From the 35th to 48th mile the ballast consists almost entirely of broken stone and debris from the rock cuttings, as no gravel was available.

There are seven stations on the line, about 7 to 8 miles apart. At all stations there are passing places or loops, with up and down platforms, except at Ross, Ballinahinch, and the terminus, Clifden. The greatest distance of the single line without a passing place is 12½ miles, between Recess and Clifden.

Starting from Galway, Moycullen Station is 7¾ miles, with goods store, up and down passenger platforms 100 yards each, cattle bank 90 yards, goods platform 55 yards; Ross Station, 12 miles, with single platform 100 yards; Oughterard 16½ miles, which last is a local terminus and provided with a turntable cattle bank 170 yards long, goods store with internal line, tank house, up and down passenger platforms each 100 yards long, and goods platform.

The next station is at Maam Cross Roads, 26½ miles, where there is also a cattle and goods bank or platform, goods store, and tank-house. At 35½ miles there is Recess Station on Glendalough Lake, the centre of the tourist district, and from which roads branch north, south, east, and west. The Ballinahinch Station, 40¾ miles, stands at the

head of Ballinahinch Lake and River, famous for salmon and white trout fishing, and has a goods store and siding.

From Ballinahinch westward there is a long stretch of wild and rugged country before reaching the terminus at Clifden, 48 miles, which has one platform, station building with residence for station-master, goods shed with internal line, cattle and goods banks, large engine shed, turntable, coal stage, and tank.

As to the architectural features of the station buildings it is not proposed to enter beyond saying that they are very permanent structures, in fact, equal to average main line buildings, and they may strike the tourist as being more elaborate than the generally wild surroundings would warrant, but doubtless the Midland Company had good reasons for this. The buildings are situated generally in the centre of the platforms, with concrete foundations, and the walls are built of hammer-squared rubble masonry, with vertical and horizontal joints in cement, the stone used being limestone (of which there are excellent quarries between Galway and Oughterard), and where the stone of the district is unworkable, they are built of red brick roofed with Major's patent red tiles, which have a picturesque appearance.

The dressings of windows and doors in some station buildings are of brick and in others of cut limestone. Platform walls are of the general type. The foundations are of concrete. The passenger platform walls consist of concrete backing and brick facing, together 18 inches thick. The facing of blue brindled brick has a row of headers for footing course, then four rows of stretchers, one row of headers, four rows of stretchers, and the three corbelling courses.

The passenger platforms are coped with concrete blocks

cast in moulds; these are 2 feet 6 inches wide, and 5 inches thick, with an overhang of 12 inches from the general face of wall, and toothed and corbelled underneath with three courses of brick, one (toothed) being on edge and the other two corbelled on the flat.

The distance from the edge of coping to the nearest rail is 2 feet 4 inches, and from face of wall to nearest rail 3 feet 4 inches, and the height from rail to top of coping is 3 feet for passenger platforms. The heights of goods and cattle bank platforms vary from 3 feet 6 inches to 3 feet 9 inches, and they are coped with limestone.

Probably the most interesting engineering work on the Railway is to be found in the bridges. The bridge over the Corrib River, however, demands special atention, and will be described further on.

Commencing at Galway, the first important bridge is that over Forster-street (on the skew, angle 85 deg.), which consists of four spans—three spans being 30 feet each and one of 36 feet over the street. The clear height from the street is 15 feet 3 inches to the bottom of the girder. The masonry in abutments and piers is heavy squared limestone with drafted quoins and copings all showing the rock face. The main girders are of wrought-iron 3 feet 3 inches deep, stiffened at intervals as shown, and weighing 4½ tons each. Steel trough flooring is laid transversely between the girders and asphalted. The troughs contain the sleepers, which are embedded in clean gravel ballast. The total weight of iron and steel in the bridge is 77 tons.

The next work is Prospect Hill Bridge, which is built in the form of a tunnel, but is really a cut and cover. It carries Prospect Hill roadway over the railway, and also acts as a retaining wall to the town service reservoirs. It was thus designed to save the expense of retaining walls of large section, which the great height of open cutting

would otherwise necessitate. It also afforded desirable building sites close to the town. (Plate XII., Fig. 2.)

The work is in a cutting, with a maximum depth of 36 feet, through boulder clay, which was so stiff that it required very little timbering, although some was used as a precaution; the sides and bottom were therefore excavated to the exact form of the bridge (or tunnel walls), and the brickwork was proceeded with in 15 feet lengths, and covered in as the arch and haunching were completed for each length. It had to be worked from one face, as the material could be disposed of only in this way. As the excavation proceeded, several springs were encountered, and these were led by 6 inch cast-iron pipes to catch-pits built under the invert, and all connected together by a 9-inch cast-iron pipe running the full length of the tunnel. The invert consists of concrete faced with two layers of brick on edge, and is segmental and laid in cement mortar; the sides and crown consist of five rings of brickwork built in lime mortar, and the haunching is of rubble masonry. The faces are of hammer-squared limestone of an ornamental character. The length from face to face is 240 feet, the extreme width is 17 feet 8 inches, and the height from rail level to crown of arch is 15 feet 1 inch. The whole is situated on a 12-chain curve.

The next bridge of importance is that which carries the railway over the Headford-road, on the skew, by one span of 28 feet 10½ inches. The girders weigh 3 tons each, and the trough flooring is similar to that described for Forster-street Bridge. The total weight of ironwork and steel is 18½ tons. The masonry is coursed rubble in lime mortar; the foundations consist of Portland cement concrete 6 to 1. The next bridge is that over the Corrib River, which will be described in detail further on.

Bridge No. 5 is that over the Woodstock River, at

$4\frac{3}{4}$ miles; it is 30 feet square span, with wrought-iron plate girder superstructure and steel trough flooring, which carries the road, and is similar to the details shown; it presented no difficulty. The total weight of ironwork in this bridge is about $18\frac{1}{2}$ tons; the main girders are 34 feet long and 3 feet deep.

Bridge No. 6 is 40 feet span on the skew, and carries the railway over the drainage canal at Moycullen, leading to Ballyquirk Lake, at $6\frac{3}{4}$ miles, with an angle of skew of 40 degrees. The main girders are 48 feet long by 3 feet deep; the total weight of ironwork is about $26\frac{1}{2}$ tons, and the masonry in abutments is squared rubble masonry in cement mortar.

Bridge No. 7 carries the railway over a drainage canal at $8\frac{1}{8}$ miles; it is 49 feet span on skew, with cross-girders 4 feet centre to centre carrying 5-inch longitudinal floor troughs. The total weight of ironwork and steel is 35 tons. The masonry is similar to that in other bridges.

Bridge No. 8, at $8\frac{1}{2}$ miles, is the Drimcong River Bridge; it is 30 feet span on the skew of 45 degrees. Here the foundations were rendered difficult on account of water and the depth to which they were sunk. The ground at this place consists of a light layer of peat overlying a considerable depth of marl, evidently an ancient lake bottom. The water came into the foundations so quickly that the lower 6 feet or 7 feet could not be kept dry, and was filled in with dry rubble, which acted as a sumph hole for the 10-inch centrifugal pump. Then several feet of concrete were put in before the masonry was commenced. No traces of yielding in the dry rubble have been detected.

Bridge No. 9 carries the railway over the Knockbane River at 10 miles; the span is 23 feet 1 inch on the skew of 60 degrees, iron plate girders, with trough flooring, carrying the railway. The total weight is 13 tons.

Bridges Nos. 10 and 11 are 30 feet spans of the type above described, and presented no difficulties.

Bridge No. 12 carrying the railway over the Owenriff River near Oughterard, at $17\frac{1}{8}$ miles, is 40 feet span, with wrought-iron plate girders, and steel trough flooring carrying the railway. The total weight of iron and steel is $26\frac{1}{2}$ tions. Some difficulty was experienced with the foundations, which were below the bed of the river, owing to the presence of gravel which was waterlogged. The pump working in this could barely keep the water under. About 12 inches of flat heavy stones were put in, then a kind of coarse bag or chamber was formed for the concrete by lining the sides and bottom of the excavation with roofing felt and disused tarpaulin; this effectually prevented the water from flowing through the concrete, and, consequently, the cement was not washed out. The pumps, however, had to be kept working night and day until the masonry reached ground level.

Bridge No. 13 is 20 feet span, No. 14 is 40 feet span, No. 15 is 30 feet span, No. 16 is 20 feet span, No. 17 is 23 feet span, all between the 18th and 28th miles, with wrought-iron superstructure and steel trough flooring, and presented no difficulties.

Bridge No. 18, at $28\frac{3}{4}$ miles, carries the public road leading to Clifden over the railway at an angle of skew of 60 degrees, and is constructed of masonry, with brick arch of five rings of brick in cement mortar, with dog's tooth on the face. The face work is of blue brindled brick, and the interior of Bridgewater brick.

Bridge No. 19, at 31 miles, is an ordinary river bridge of 20 feet span, similar to those above described. The foundations of this bridge are on gravelly clay, underlying peat about 7 feet 6 inches deep. Immediately over the clay

were found several pieces of charred fir timber, suggestive of an ancient forest fire.

Bridge No. 20, at 32¼ miles, carries the railway over a river on the skew with 30 feet span; the superstructure is similar to one of the spans of Forster-street Bridge.

Bridge No. 21, at 33¼ miles, has also 30 feet span; it is similar as to superstructure, and carries the railway over Lissoughter River on the skew; the abutments are very high, with long splayed wing walls and retaining walls to river; the foundations are on rock appearing on general ground surface.

Bridge No. 22 is called Weir Bridge, at 35¾ miles. It carries the railway over a river joining Glendalough and Derryclare Lakes. The span is 30 feet, and similar to those above described. The abutments were built of msonry in mid-river, within cofferdams, on a concrete footing.

Bridge No. 23, at 37¾ miles, is 20 feet span, and carries the railway over a small river.

Bridge No. 24, at 40¾ miles, carries the railway by two spans of 50 feet, over the Cloonbeg River at Ballinahinch, and is built on a curve of 24¾ chains. The superstructure weighs 66 tons; the permanent way is carried on cross-girders and steel through flooring, as described below. The river is shallow, but rapid; the centre pier is built on rock close to the bed of the river, and is buttressed up stream.

Bridge No. 26, at 46¼ miles, carries the public road leading to Clifden over the railway, and is built similar to No. 18.

Bridge No. 27, at 46¾ miles, also carries the public road over the railway. The public road was diverted for this purpose to avoid level crossings. The span is 15 feet 4 inches on the square, and 17 feet 8½ inches on the skew, the superstructure being trough flooring, which supports the

roadway and plate girder parapets. The total weight is 13 tons. The abutments were built of blue brindled brick throughout, backed with concrete, with displacers.

Bridge 28, at 47⅜ miles, carries the railway over the river at Clifden by a skew span of 49 feet. The superstructure is of a type similar to the 50-feet spans above described.

There are 13 small accommodation bridges over and under the railway, mostly under, with spans of 12 feet clear, with iron tops of the trough flooring pattern running parallel with the railway.

The Corrib Viaduct, which carries the railway over the River Corrib at Galway, consists of three spans, each of 150 feet, clear between bearings, and a lifting span of 21 feet, on the bascule principle, to provide for the navigation. (Plates XIII., XIV., and XV.) The girders for the large spans are lattice, with ties in pairs sloping downwards from each abutment to the centre at an angle of 45 degrees, near which they are met by a series of similar bracings for counterbracing purposes, inclined in the opposite direction. Vertical struts, in pairs, occur at every 7 feet 6 inches of the length, and the ties and struts are attached by gussets at the top and bottom to open trough girders which form the top and bottom booms. The end pillars are similar to the top and bottom flanges, and are inclined from the bottom towards the centre of the span at an angle of 63 degrees 27 minutes to the horizontal. The camber in the large spans is 2½ inches. Each pair of vertical struts is wind-braced by a single system of flat bars, and the top flanges or booms are strongly braced overhead, and stiffening T-bars are inserted between the top bracing and the vertical struts at an angle of 45 degrees. The flooring consists of Hobson's patent arched steel flooring plates, of a special section ⅜ inches thick, strongly

riveted to the side of the trough flanges or booms and resting on the bottom L-iron of the same. The troughs are semi-elliptical in cross-section, rising 9 inches in the centre, and each covering 2 feet 6 inches in length of the span. The actual weight of the 150-feet span is 112 tons 5 cwt., and of the lifting span, with machinery, 36 tons 16 cwt. The total dead load on each span is 213 tons 12 cwt., and the live load was calculated at $1\frac{1}{3}$ tons per foot run.

The whole flooring is levelled up to $\frac{3}{4}$ inch above the crown of trough with tar asphalte; by this method of construction the ordinary cross-sleeper road could be carried across the bridge on ballast 3 inches under the sleepers, and up to top of level of same, except on the lifting span, where longitudinal timbers had to be laid without ballast. The lifting span consists of plate girders with small cross-girders and rail-bearers, the balance weights of the machinery for actuating the span weigh $18\frac{1}{2}$ tons, and drop into slots in the masonry of the pier.

In erecting the superstructure the bottom boom was first laid down on a temporary staging, fixed accurately in line, and wedged up to the required camber; the flooring was then put on, the end pillars and struts erected, and the top boom lowered on to these. The riveting was all done by hand.

The bridge is protected by home and distant signals; and is electrically locked from the Galway signal cabin, but it has also a cabin of its own with five levers situated at the western end. By an ingenious arrangement, the bar which locks the opening span, once it has been withdrawn, and the bascule has been lifted the smallest distance, it cannot be shot back until the bridge is again fully closed. The arrangement which cuts off the wire connecting the signals at the east end is also very neat. Each of

the large spans has a fixed end and a roller end moving on steel rollers fixed in a frame. Two wheel guards are carried across the bridge, each consisting of a longitudinal bulk 8 inches by 8 inches, protected at the upper inside edge by 3 inches by 3 inches by $\frac{3}{8}$ inch L-iron screwed on to balk by coach screws on top and by countersunk screws on sides. The angle-iron stands $2\frac{3}{4}$ inches from outside of rail and rises 3 inches over it.

As to the foundations; those of the east abutment, which were situated clear of the river, are formed of Portland cement concrete; that of the west abutment being full of springs, the concrete was put in in bags. No. 1 pier, at east side of river, was built inside a timber cofferdam, and the foundations are of concrete 4 to 1, with masonry footings on hard boulder clay. The foundations of the two piers carrying the lifting span are each of two wrought-iron cylinders, riveted on a staging over the position they were to occupy when lowered; those in No. 2 pier were the first sunk, and great difficulty was experienced in bringing them to a level bearing all round; owing to the presence of large boulders, they both canted when the internal lining of brickwork was put in, and in straightening one of them the brickwork was so cracked as to require to be taken out and rebuilt; when they canted they were so securely held by the surrounding boulder clay that they could not be lifted up by the Goliath in use, and they were too small inside to enable divers to work with ease at the cutting edge, while the boulder clay was so porous that a 9-inch centrifugal pump and a No. 7 pulsometer, working together, could not control the water; consequently the divers worked down to the cutting edge outside the cylinders, and by blasting and excavating the boulders which were holding up the cylinders, succeeded in straightening them and bringing them up to a uniform bearing.

The excavation thus made around the cylinders was then filled up with concrete in bags, and concrete in bags was also put in the centre chamber, which was filled with concrete by skips. They could then be pumped out, and concrete was put in dry in one of them; however, owing to the disturbance and strain put upon the riveting and joints of the cylinders in the process of straightening them, they could not be rendered water-tight, and in the next cylinder the concrete was all put in in skips, and no attempt made to pump it. The experience gained in sinking these latter cylinders enabled those of pier No. 3 to be got down and filled very quickly; they were hung up by the Goliath and no brick filling was put in until they were finally fixed, except some filling in the annular portion between the inside and outside ring to make them sink. In this position they weighed about 40 tons. They were then lowered between guide piles until they touched the bottom, and sank through the mud into a foundation that held them; the Goliath was then braked, and they were held at this level until the divers had excavated away the points of support; they were then lowered down, and the next point of support observed and removed, and so on until a uniform bearing was obtained. Then a layer of bags of concrete was put in, and over them fine concrete, and when these had sufficiently set it was found that the pulsometer could control all leakage sufficiently to allow the masons to complete the brick rings up to water level. Caisson No. 4 took 24 days in sinking. Even in these cases it was not considered advisable to put in the centre core of concrete dry, as the cement got more or less washed out by the pump, and consequently the whole was put in with skips. The masonry commenced at low-water level, and was hearted throughout with 4 to 1 concrete. Each cylinder is raised in masonry 2 feet 4 inches to the spring-

ing of an arch which connects the two cylinders of each pier. The character of the masonry is coursed ashlar in uniform courses, each stone having an inch draft along courses and on vertical joints, and showing the rock face on the surface between. The ends of each pier are semicircular, of 5 feet 8 inches radius, and the pier is surmounted by a corbelled stringcourse 3 feet high. The bedstones on which the superstructure rests are of Cornish white granite, and all the remainder of the masonry is of Galway carboniferous limestone, of a dark grey colour. The superstructure was laid down on a timber platform or staging 31 feet wide, carried on rows of piling, three piles of 12 inches by 12 inches to each, spaced 20 feet apart, each row being diagonally braced. Iron rails were laid on this platform, and on it the Goliath crane (span 30 feet) 6 inches), and steam derrick could be run backwards and forwards the whole length of the bridge. There was also a low-level timber bridge which accommodated the passage of the contractors' engines with material for the foundations, &c.

The manufacturers of the steel and iron work in the superstructure were Messrs. Cochrane and Son, and for the cylinders Mr. T. Butler, of Stanningley. The signalling was done by the Railway Signal Company of Fazakerly. The contractor for the entire works was the late Mr. Travers H. Falkiner, with whom was associated Mr. E. J. Jackson.

Besides rivers, a large number of streams had to be crossed by culverts varying in size from 2 feet to 12 feet; these are built in rubble masonry in cement with stone inverts. The longest was that in a deep ravine known as Munga Ravine, at about 44¾ miles, and which was about 40 feet deep; a viaduct was originally intended, but as sufficient material was subsequently acquired in the vicinity an embankment was adopted; as the railway crosses the

ravine on the skew, it necessitated a culvert of 112 feet in length and 12 feet in width. It is built of rubble masonry in cement, with brick arching; the walls are 5 feet thick, with counterforts 4 feet by 3 feet. Wing walls 25 feet long were built to catch the slopes of embankment. The 18-inch drains are flagged at the bottom with flags 4 inches thick let 4 inches under each wall, and were covered on top with flags 5 inches thick bearing at least 6 inches on side walls. Where the railway traverses very sidelong ground, as on the mountain side, a larger number of culverts had to be constructed than usual, to provide for any sudden rush of water; in many instances these culverts were stepped to suit the declivity of the mountain stream, and a retaining wall, 370 feet long, had to be built on the railway side of Clifden River at 47 miles to meet this case of sliding ground; it is 12 feet high, 2 feet thick at top, 5 feet thick at bottom, and is built of rubble in cement mortar to flood level, and above that height of stone rubble.

It only remains to add a few general remarks on matters of detail. It will be noticed that the average number of bridges are small for 50 miles of railway. To avoid their frequent occurrence and preserve the alignment of the railway at the same time was no easy task for the engineers, through a wild country abounding in bog, lake, and mountain.

Generally in the ironwork superstructure of the bridges, the girders were designed to have a height of one-tenth of the span, and are plate girders with strong stiffening, and up to and including 45 feet span the flooring is steel trough flooring, full height 1 foot $1\frac{1}{2}$ inches, consisting of $\frac{1}{2}$ inch plate with double cover-plates 7 inches by $\frac{1}{2}$ inch at top and bottom of each trough; the distance from centre of one trough to corresponding centre of next is 2 feet 4 inches,

and they are attached to the web of girder by $3\frac{1}{2}$ inches by 3 inches by $\frac{1}{2}$ inch L-iron; they rest on, and are riveted to, the bottom I-iron of flange of girder. A 1-inch screw tap is let into each end of the bottom of each trough for drainage purposes, and in cases of bridges over public roads, these are connected by cast-iron gutters and down-pipes. The under sides are painted uniform with girders, and the tops are asphalted and filled with clean ballast, into which the sleepers are bedded, thus obtaining a through cross-sleeper road. The 49 feet and 50 feet spans have got cross-girders 15 inches high, consisting of flanges 9 inches wide connected to webs by L-irons and resting on bottom flange of main girders; these are covered by 5 inches corrugated or trough flooring laid longitudinally, and differing slightly from the other flooring described, in this particular, in having no covering plates to the troughs, except where they are introduced for the purpose of joining the flooring together, that is, at every third corrugation. The cover-plates are 4 inches by $\frac{3}{8}$ inches. There are holes in the bottom of each corrugation at intervals for drainage. As none of the main girders rise more that 2 feet 6 inches over rail level, they were designed to be placed 14 feet apart centre to centre; where the spans are skew the troughing is cut to a straight line parallel to the abutment face of bridge, and 12 inches inside that face, and the end of the trough is kept from spreading by a $1\frac{1}{2}$ inch wrought-iron bolt, which passes through from side to side of trough. Bed-plates are of cast-iron, 2 inches thick; the bearings vary from 2 feet to 2 feet 6 inches.

The manufacturers of the ironwork of all the bridges, except the Corrib, were Messrs. Joseph Westwood and Co., Poplar, and J. Butler, of Stanningley.

In connection with the subject of bridges, it will be interesting to give the results of tests made by General

Hutchinson, and subsequently by Major Marindin, of the Board of Trade, when inspecting the line. The tests made of bridges between Galway and Oughterard were with three locomotives, each weighing 43 tons, and were recorded by means of rods, and on the Corrib Bridge by the level.

On the Corrib Bridge the results were, for each of the 150-feet spans, a deflection of 1 inch, with no permanent set, and $\frac{3}{16}$ in. under trough flooring.

In Forster-street Bridge.	Deflection.
First span, of 30 ft.	$\frac{3}{16}$ in.
Second span, of 36 ft.	$\frac{3}{16}$,,
Third span, of 30 ft.	$\frac{3}{16}$,,
Fourth span, of 30 ft.	$\frac{1}{8}$,,

	Deflection.	
In Headford-road Bridge, 28 ft. $10\frac{1}{2}$ in. span;	Girder, $\frac{1}{8}$ in.;	troughs, $\frac{1}{16}$ in.
In Woodstock Bridge, 30 ft. span ...	,, $\frac{1}{8}$,,	
In Ballyquirk Bridge, 40 ft. span ...	,, $\frac{1}{8}$,,	
In Moycullen Bridge, 49 ft. span ...	,, $\frac{1}{8}$,,	
In Drimcong Bridge, 30 ft. span ...	,, $\frac{1}{8}$,,	
In Knockbane Bridge, 23 ft. span ...	,, $\frac{1}{16}$,,	
In Ross Bridge, 30 ft. span	,, $\frac{1}{8}$,,	
In Loughtgannon Bridge, 30 ft. span ...	,, $\frac{1}{16}$,,	
In Oughterard River Bridge, 40 ft. span	,, $\frac{3}{16}$,,	
Leadmines Bridge, 20 ft. span	,, $\frac{1}{8}$,,	
In Glengowla River Bridge, 40 ft span ...	,, $\frac{1}{8}$,,	
In Garibaldi River Bridge, 30 ft. span ...	,, $\frac{1}{8}$,,	troughs, $\frac{1}{16}$ in.
In Leam River Bridge, 30 ft. span ...	,, $\frac{1}{8}$,,	to $\frac{3}{16}$ in.
In Letterfore River Bridge, 20 ft. span ...	,, $\frac{1}{16}$,,	
In Bunscanniff Bridge, 23 ft. span ...	,, $\frac{1}{8}$,,	troughs, $\frac{1}{16}$ in.
In Boheshal River Bridge, 20 ft. span ...	,, $\frac{1}{16}$,,	
In Derryneen River Bridge, 30 ft. span ...	,, $\frac{1}{8}$,,	troughs, $\frac{1}{16}$ in.
In Cahir River Bridge, 30 ft. span ...	,, $\frac{1}{8}$,,	
Weir Bridge, 30 ft. span	,, $\frac{1}{8}$,,	
Athry River Bridge, 20 ft. span ...	,, $\frac{1}{8}$,,	troughs, $\frac{1}{8}$ in.
Cloonbeg River Bridge, 50 ft. span ...	,, $\frac{3}{16}$,,	cross-girders, 0 in.
Clifden River Bridge, 49 ft. span ...	,, $\frac{1}{8}$,,	cross-girders, $\frac{1}{16}$ in.

The culverts are built of rubble with roughly squared rubble arches, and are almost all coped with

hammer-squared limestone from Oughterard, and many of them have quoins of the same. In deep bog lands (where considerable saving might have been effected in foundations by the use of wooden box culverts they were not approved of, except in a few instances, by the working company), the foundations consist of a dry rubble base surmounted by a layer of Portland cement concrete 6 to 1. Earthenware pipes 12 inches and 18 inches have been used in a few cases, the exposed ends being cased in concrete. One or two flat-top culverts are built, the superstructure being 4 inches creosoted timber carried on light iron girders placed under each permanent rail.

In conclusion, the author wishes to record his thanks to Mr. E. J. Jackson and Mr. J. Tatlow, A.I.C.E.I., for the originals of some of the plates illustrating this paper, also to his Resident Engineer, Mr. C. E. Moore, for those showing the progress of the works.

Mr. James Dillon said he had great pleasure in rising to congratulate the author of the paper on the very able and perfect manner in which he had brought the details of such an important railway before the Institution, and also for the large amount of details which he had been able to bring before them.

With reference to the Corrib Bridge, he thought it would be most desirable if the photographs relating to this particular part of the work could be printed with the paper, and any other photographs, as, in the judgment of the Council they thought desirable. Of course he knew it was a source of expense, but they would prove most useful and valuable if they were copied into the Transactions of the Society.

He would like a little more information about the way in which the lifting portion of the Corrib Bridge had been

dealt with, and how much headway was secured, also some information about the cost of that structure. This information would be particularly interesting, as the Corrib Bridge was somewhat different to the general class of bridge in this country.

There was another matter which was of interest, and that was, out of the 48 miles of railway how many miles of it passed through bogland? What proportion of it was on solid ground, and what proportion on bogland? He would also like to know the cost per mile of the railway over the bogland. It was very important to engineers to know the relative cost of the construction of railways across boglands. Sometimes this work presented great difficulties. He remembered a case where a bank of 25 ft. was left completely finished on a Saturday, and on the following Tuesday the entire bank disappeared, owing to the bog yielding and swallowing up the whole bank. He might mention that the bog had not been properly treated, and this was the reason of the failure.

There was another feature connected with the paper which the author, no doubt suffering from bashfulness, had not said very much about. There was a population of 60,000 people living along the coast of Galway. The grant for the railways was given for the development of Fisheries and other Irish industries, and it would be natural to think that the line would have been constructed where the greatest number of people engaged in such industries lived. Great efforts were made to have this coast route adopted. The Midland Great Western Railway Company thought it was the best route, and stated so publicly, and other people also, but the Royal Commission for Irish Public Works did not think so, and they had it laid out from Galway to Oughterard, and thence into Clifden, away from the 60,000 coast population, though at that

time it was said the remains of two or three houses only could be seen along the proposed route between Oughterard and Galway. It would be interesting if they could throw some light as to why this 48 miles of railway was laid down to avoid these 60,000 people engaged in fishing and other industries.

There were several other plans for railways proposed and submitted, but they were all rejected. A line was tried in another direction, but it was not successful. It was known as the "Switch-back Railway." This line was a failure, and subsequently the present line was constructed, and a good, level coast line route abandoned—the author and himself (Mr. Dillon) having laid out this latter proposed coast line.

Mr. Tatlow said, as manager of the Midland Great Western Railway, he took a considerable interest in the Galway and Clifden Railway. He did not rise in any way to criticise the paper from an engineering point of view. He wished simply to add his meed of praise to what had been said by the author as to the excellence of the railway. He did not intend to say anything about the rival routes proposed. The line was constructed now, therefore it was idle to discuss which would have been the best way. The line was doing a great benefit to the West of Ireland.

He was most concerned about receiving a well-finished article from the engineer—a line with easy gradients and easy curves, well constructed, and with good station accommodation. This Western line certainly possessed all these. But it must not be imagined that this excellent railway was solely due to the Government grant. The Government gave £264,000, but if that had been all the money advanced, a railway so successful could never have been built. The Midland Great Western Railway

gave about £146,000 on the construction, and in addition spent between £30,000 and £40,000 in the matter of rolling stock. The total cost of the line worked out at £9,000 per mile. When this line was opened in 1895, it was said the principal design was to promote and cultivate the fishing industries in the West of Ireland. It has been very successful. The Cleggan fisheries, which are a few miles distant from Clifden station, have been considerably increased. It is principally mackerel fishing that they do.

In the year	1896	they yielded	398	tons.
„	1897	„	343	„
„	1898	„	845	„
„	1899	„	861	„
„	1900	„	1,437	„

and in the year 1900 there were 397 tons of fish forwarded from Ballinahinch.

These figures show what benefit the railway is to the country. Anyone who visited this part of the country some years ago would remark the great improvement that had taken place in the country within the last few years, and they will see the advantages that have accrued. Undoubtedly for the first year or two when this Galway line was opened, also the Achill, Mallaranny, and Killala extensions, the Midland Company in working them assumed a great burden. The result was that for a year or two at any rate their dividend came down to 4 per cent., and their receipts were very considerably diminished per mile of railway. But the traffic on the line has been gradually developed. The railway involved a very large working expenditure, and it would be years before the line would pay. One of the chief sources of profit would be the tourist traffic. They had established a hotel at Recess and other places, and the number of tourists was undoubt-

edly satisfactorily increasing. He thought there was no doubt the line being made in the West of Ireland had very much improved the poorer districts, and it was a gratification to think this had been done by the Government, aided by the liberal assistance of the Midland Great Western Railway Company.

The PRESIDENT said he agreed with Mr. Tatlow that there was a great deal to be said about the paper from other points of view than that of the engineer. The question of the best route was a very important one, and one on which there was some difference of opinion. He remembered a good many years ago travelling from Clifden to Galway on a mail car. But all that was now changed, thanks to the Midland Railway Company and the progress of engineering.

The description of this light railway differed very much from what they were accustomed to hear—where they had gradients of 1 in 30 and 1 in 40. But it was easy to see why they had such a well laid out railway, when they heard that £9,000 per mile had been paid for it. £3,000 to £5,000 per mile were generally considered the right figures for the cost of light railways.

The AUTHOR, in reply to Mr. Dillon's question regarding the cost of the Corrib River Bridge, said that this will be found in the appendix. In reply to the question regarding length of line through boglands, this is also set out in the appendix. Respecting the route of the railway, which Mr. Dillon refers to in the latter portion of his remarks, the author regrets he is unable to throw any light on the subject beyond the fact that the constructing company (the Midland Great Western Railway) had to build the line on the route recommended by the Government Commission, and for which the free grant of money was allocated.

—	Unit	Quantity	Rate £	s.	d.	Amount £	s.	d.
1. Wrought iron in permanent caissons	Tons	50	36	0	0	1,800	0	0
2. Cast iron in bedplates, fixed and lifting spans, &c., and in checkplates of lifting span	,,	9	13	10	0	121	10	0
3. Cast iron in balance weight	,,	18½	8	10	0	157	5	0
4. Steel in main girders, wind bracings and cross girders of fixed spans, and cross girders and rail bearers on piers	,,	250	22	0	0	5,500	0	0
5. Steel in Hobson's patent arch plate flooring of fixed spans	,,	86	22	0	0	1,892	0	0
6. Steel in main girders, cross girders, rail bearers, floor bars, wind bracing, and hand-rail standards of lifting span	,,	9	24	0	0	216	0	0
7. Steel in rollers, and pins of rollers, and fixed bearings of large spans	,,	2½	32	0	0	80	0	0
8. Machinery in lifting span, including steel axles, cast-iron pedestals, cast-iron sectors, and pinions, and chains, shafts and bearings, winch gear and brake, also apparatus as specified for locking and wedging tail end	Lump sum	—		—		550	0	0
9. Bolts, nuts, and washers, including lewis bolts and lead filling	Cwt.	12	24	0	0	14	8	0
10. Excavation in cylinders, including air pressure or otherwise, clearing of water, pumping and staging	Cub. yds.	275	3	0	0	825	0	0
11. Excavation in foundations of No. 2 Pier, including coffer dam, or otherwise clearing of water, pumping and staging	,,	116	2	0	0	232	0	0
12. Excavation in abutments	,,	400	0	8	0	160	0	8
13. Concrete in cement in cylinders and elsewhere—strength 4 to 1	,,	68	1	5	0	85	0	0
13. Concrete in cement in cylinders and elsewhere—strength 5 to 1	,,	68	1	3	0	78	0	0
13. Concrete in cement in cylinders and elsewhere—strength 6 to 1	,,	400	1	0	0	400	0	0
14. Brickwork in cement, in cylinders	,,	296	2	8	0	710	8	0
15. Brickwork in arches of Piers Nos. 2 and 3	,,	27	2	10	0	67	10	0
16. Masonry in abutments and piers	,,	1,480	1	18	0	2,717	0	0
17. Masonry in copes of do.	,,	33	4	14	6	155	18	6
18. Granite in bedstones on abutments and piers	,,	54	6	15	0	364	10	0
19. Breeze concrete in flooring, as per Clause No. 25A	,,	120	3	7	6	405	0	0
20. Gas-pipe hand-rail, 1¼ inches diameter	Lineal feet	50	0	2	6	6	5	0
21. ,, ,, 1 inch ,,	,,	107	0	1	6	8	0	6
Total amount delivered and fixed complete	—	—		—		£16,545	19	0
Maintenance for twelve months	—	—		—		200	0	0
TOTAL	—	—		—		£16,745	19	0

BILL OF QUANTITIES, GALWAY AND CLIFDEN RAILWAY.

—	Quantity	Price	—
		£	£
Per mile, bog formation, including drains, fascines, and brushwood, as specified	12	700	8,400
Do., exclusive of fascines and brushwood, 4 drains	1⅓	400	450
Do. do. 2 drains	2	300	600
Do., brushwood in peat embankment, as specified - - - - -	5½	400	2,200

[15th May, 1901.]

MR. EDWARD GLOVER, President, in the Chair.

Messrs. R. G. ALLANSON-WINN and JAMES JOLLY were elected as Members; BRYAN E. F. SHEEHY and CHARLES E. S. CRAWCOUR, as Associate Members, and THOMAS J. O'NEILL as Associate.

NOTES ON ROAD CONSTRUCTION.

By. R. G. ALLANSON-WINN.

THE primary intention of those constructing roads, whether mule tracks, 10ft. baggage animal tracks, or full-sized Macadamised roads for general traffic, has always been to provide an easier and quicker means of communication between two places than the natural conformation of the ground affords. Thus, if A and B are two towns, they may be five miles or 100 miles apart, their difference in level may be 5 feet or 5,000 feet, the object—having due regard to the kind of traffic which will use the road—is to make the transit from one to the other easier, quicker and safer.

How often have the most important conditions been lost sight of altogether, either through undue haste in settling upon the alignment, or ignorance of the best gradients to take, or where to save distance by judicious cutting! Monuments of such faulty alignments exist all over the world.

There is a story told of one of the Eastern magnates who employed an European engineer to make a road from an important town at the foot of a range of mountains over a lofty pass, and then on to another town some miles away in the plain at the other side of the range. The engineer

pegged out his zigzag up to the pass, and then down the other side, taking a gradient in both cases well suited to the expected traffic. He then, as there were no obstacles of any kind, took a perfectly straight line from the point of leaving the foot of the mountains to the town to be reached. In this he was quite correct, but the potentate who came to inspect the work was much displeased, and said the straight line was not pretty, and that he insisted upon having the road zigzagged across the plain so as to be in harmony with the zigzags over the mountain range!

As a much steeper gradient may be allowed for a bridle-path or pack-horse track than for a tonga or carriage road, the actual distance of the first-named will be shorter than the others. On an ordinary road, what we call a level road across flat or gently undulating country, about 1 in 35 or 151 feet per mile, is about the steepest slope allowable for trotting horses. In crossing mountain passes, however, much steeper gradients are often necessary, and 3° to 5° may be occasionally used, though 2·5° should not be exceeded except when absolutely necessary to save in cost. That is to say, a rise of about 4½ feet in 100 feet should be looked upon as a safe limit for a mountain road. Reference may be made to Trautwines' table of grades per mile and per 100 feet, measured horizontally, and corresponding to different angles of inclination.

It was the author's original intention to deal with the subject in two separate papers, one of which was to have been devoted to mountain roads and tracks and the other to first class Macadamised roads for heavy traffic; the time available for the preparation of this paper renders it impossible to prepare all the illustrations, and it has been therefore decided on this occasion to lightly touch on certain difficulties encountered during the construction and maintenance of the Jheelum Valley and Gilgit mountain

roads and the construction of the Baramula-Srinagar high road through the valley of Kashmir, reserving for a future occasion fuller details and illustrations.

There are so many points to be decided before fixing on the alignment of any important road where natural obstructions are many and varied that the engineer's common sense and judgment are often severely taxed, and it is, of course, impossible to lay down any hard and fast rules. It is hoped that it will be within the scope of this short paper to indicate some of the more important difficulties which are likely to constantly crop up, and which have come directly under the author's notice.

There are two or three points of especial importance outside all technicalities. All engaged upon the work, or in any way interested, should be quite clear as to what is expected of the road, and what is the primary object in ordering its construction.

It may be that you have to run a mountain road over high passes as quickly as possible, and that such road is intended to expedite the carriage of munitions of war. In such a case there is probably no time in which to decide upon the very best possible alignment; you fix upon one which seems fairly good and with clinometer in your hand and a couple of assistants with staves, you run out several miles a day—many hundreds of coolies or navvies cutting out the road as you go along. Long distances on the Gilgit strategic road were thus constructed by the contractors, Messrs. Spedding & Co., at the time of the Hunza-Naga campaign.

On the other hand, you may have to lay out a very good permanent road which is to open up a country and facilitate the transport of produce, and so increase the commercial prosperity.

In this case more time will be at your disposal, and you

will, after much thought and care, select a satisfactory alignment, and arrange to put in thoroughly good and lasting work.

In a country of rivers, dykes, and swamps too much care cannot be taken in the selection of bridge sites, and it would be well, therefore, having first roughly made out the approximate direction the road should take, to select all important bridge sites with the view of securing safe approaches, good foundations for abutments and piers, and an economy if possible in cost. Indeed it is hardly going too far to say that economy is certain to be effected in the long run if all these matters are earnestly considered before the line is finally pegged out.

For example, if an approach is made at a dangerous angle to the centre line of the bridge accidents may result in orders from local or other authorities for the entire shifting of the bridge and road. Sometimes a little judicious cutting and at others a longer sweep of the curve to the bridge may make things safe.

Careful borings should be made wherever abutments and piers have to be erected. The initial expense of all these precautions is more than repaid by increase of safety and the practical certainty that alterations will not be required in the future.

Then, again, in the question of waterway; it is most unwise to try to economise bricks and mortar by constructing a bridge inadequate to the requirements of the highest floods. Possibly in certain situations the difference in expense between a brick structure with piers and a good iron girder bridge may be rather heavy, but if you place your girder well above the reach of the highest floods, and look well to the abutments, you will, in the case of a single span, be pretty secure. An example is here given of a brick 60° arch bridge originally designed with insufficient

waterway. (Fig. 1.) The first flood clearly demonstrated this by topping the crown of the arch, and the author then put in a second arch, as shown, converting the right hand abutment into a pier. The arch being a flat one, care had to be taken to put in the second arch before altering the abutment, otherwise the thrust of the larger arch might have occasioned the collapse of the bridge.

Another danger to be guarded against in masonry bridges or culverts is the use of flat arches, where the abutments are high, for if you persist in having the flat arch you must increase the weight of your abutments, and thus add unnecessarily to the expense of the masonry, or else run the chance of the arch giving way. Where culverts are required in low banks 5 to 6 feet in height 60° arches may be allowable, in spans from 4 to 10 feet, but where the banks are higher the author has found it safer to use true arches. In two instances he has observed failure to result from the use of 60° arches in 10 foot banks with 10 foot spans. (Fig. 2.)

Another important point in masonry bridges is the avoidance of heavy, thick piers, which not only waste money in bricks and mortar, but take up the waterway and add to the chances of damage by floods scouring the abutments. As the piers do not take any lateral thrust, and simply carry the vertical pressure of the arches, they should present as slight a surface as possible (compatible with strength) to the flowing stream. The abutments should be of full weight, and be well tucked into the banks, so as to avoid scour and obstruction. (Fig. 3.)

A waste of material is often observed in piers, but really where flat arches are used, the generosity would be better bestowed upon the abutments, which take the thrust of the arches at both banks.

SPECIFICATIONS.

One of the most important matters to be settled before commencing work is an exact specification of what is required. As a rule—it is a rule which has many exceptions—a contractor is expected to put in good, sound, first-class work both as regards quality of materials and manner of construction. He is then expected to do the work as cheaply as is consistent with allowing him a fair profit on his outlay and risks; and lastly he should, both in his own and in his employer's interests, try to complete his work rapidly. All this probably applies to the vast majority of works given out on contract, but it often happens that a contractor is asked to run a passable road over such-and-such a range of hills with all possible dispatch. Here time is of the first importance; first-class work and cheapness come in a very bad second and third. For example, it may be of the utmost importance, and involve the saving of thousands of pounds or lakhs of rupees, to get certain troops, provisions or ammunition over a trackless range of mountains before a certain date. The lives of hundreds of fellow-creatures depend, perhaps, on the result; the contractor's terms are high, and his risks are great, but, when he has carried out the work and the road has fulfilled its functions, all parties are satisfied. The quickly built road and temporary bridges will, by the next year, require a very great deal of repair, but they have done the work specified.

In the case of a first-class metalled carriage road good rates are sure to be paid, and time of completion will probably be of secondary consideration. All the work from the construction of banks and other earthwork, such as slopes of cuttings, side drains, &c., with the quality of the materials used, should be according to specification. Where cheapness is the *first* desideratum nothing but unsatisfactory

work can be expected. Monuments of mistaken economy are to be found all along a road constructed on these terms—faulty bridge approaches, uneven surfaces, cracked arches and bulging abutments. Of course a good road may also happen to be a cheap one, but a road in which every important detail has been scamped for the sake of saving money cannot be a good one. With the view of keeping questions relating to the same subject as far as possible under one heading, it has seemed advisable to give certain specifications as regards materials and construction which have been laid down for the author's guidance in work under his charge. These directions, as they may very properly be termed, or some of them, may be found useful for reference during the construction of almost any road. (Fig. 4.)

Earth to be taken from barrow pits on either side of road and laid in even layers 1 foot high.

Slopes 1 and 2 or 1 in 3 according to sections. Between chain — and chain — allowance of 1 inch per 1 foot extra, height must be also added to allow for subsidence.

Between chain — and chain — in the marshy land 2 inches per 1 foot is to be allowed.

Surface of road to be nicely dressed to template, rising 4 inches to 6 inches to formation level in centre.

Sides to be neatly dressed off to required slopes.

Cuttings.—To be cleanly cut out according to plan, and sides dressed to required slopes.

Side Drains.—These are to be cleanly cut, in all level portions, and in cuttings, parallel to, and at equal distances right and left of, the centre line of the road, 2 feet wide at top, 1 foot at bottom, and 1 foot 6 inches deep.

Catchwater Drains.—To be cleanly cut out at such places as may from time to time be indicated during the progress of the work.

MASONRY.

Bricks.—9 inches by 4·5 inches by 3 inches, about 14 to the cubic foot or 1,400 to the 100 cubic foot.

All bricks to be well moulded and well burnt, and to pass as "first-class."

Mortar.—Lime, surkhi and sand to be all of first quality, and sifted fine before being mixed. Mortar to be ground in a mill before being used in masonry. Turning it over with spades is not sufficient. Proportions:—1 part lime, 1 part sand; or, where the lime is "fat" and slow setting, 2 parts lime, 2 parts surkhi, 1 part sand; or 2 parts lime, 3 parts surkhi.

N.B.—Surkhi to be made of well-burnt clay or well-burnt bricks—under-burnt clay is little better than mud. It should be sharp and clean, and leave no dirt on the hands when rubbed between the fingers. Sand to be also clean and sharp.

Concrete.—Any stone, clinker, or kunka may be used; it must be broken into small nodules 2 inches to 2·5 inches in greatest diameters. The concrete to be well mixed with the mortar before being used, it should be laid in the founds or elsewhere in layers of 7 inches and rammed with rammers to 6 inches. Plenty of mortar to be used and the surface to show mortar evenly on top when finished.

Stone Masonry.—It often happens that in large towns and manufacturing districts where a great deal of coal is used much care has to be devoted to the selection of the suitable kind of stone, and old buildings should be examined for signs of weathering; it should then be ascertained, if possible, from which quarries the weathered stone was taken, in order that that particular stone may be avoided in the works about to be commenced. As we are, however, dealing more particularly with country roads, the

question of the chemical action of certain gases, carbonic acid, nitric acid, &c., on stone surfaces is not likely to arise, and those who wish to study this question are referred to Mr. Dobson's manuals in Weale's series. There are, however, certain stones of porous flaking character which are always apt to weather badly, through the absorption of moisture and the action of frosts. These should, if possible, be avoided in all exposed work.

It is unfortunate that so many classes of stone which in texture and quality are admirably suited for building purposes should come out of the quarries in such bad shape and require so much dressing before fit for the mason's hands. Of such are most of the igneous rocks, granite and trap. These are for the most part extremely dense in texture, and the traps especially come out in angular, irregular pieces, with probably only one available bedding surface.

Certain of the rougher kinds of granite disintegrate very readily, and should be avoided in almost all work—they should certainly be discarded for metalling since they soon pulverise. Much granite of this description is to be found near Dublin at Dalkey, and elsewhere.

Slaty formations often produce good material for masonry; the flatness of the layers forming excellent bedding surfaces. The stretchers are easily dressed, but the headers, unless sawn or well chiselled, present a rough, jagged surface, not, however, unpleasant to the eye or detrimental to the strength of the work. It is hardly necessary to remark that the stones should be laid in beds parallel to the splitting grain, and *on no account at right angles to it.* In masonry stones should never be laid, as they are in pavements, on edge. From this faulty construction much damage may arise. When the stone, for appearance sake, and in order to present a fine large sur-

face, is laid on edge, water is apt to get in between the layers, then a frost comes, and expanding the film of water splits off a flake of the material. This cannot happen if the stone is laid with its layers parallel to the beds of the courses.

In the old red sandstone formations many excellent building qualities are to be found, and, as a rule, the deeper you get into the quarry the better and larger are the blocks obtainable. Many of these sandstones are extremely tough, and the work of dressing them is far harder than it is in the case of more brittle, though possibly closer textured stone.

Certain of the lighter qualities of the sandstone are so apt to crumble that, though they are easily dressed, and sawn into various shapes and sizes, they are not to be recommended for outdoor work. They are very absorbent, and consequently weather very rapidly in any climate subject to great alterations of temperature.

Very porous stones should be avoided since they readily absorb moisture, and suffer badly in frosty weather.

In Kerry the old red sandstone formation predominates, but there is also abundance of excellent limestone, and for ornamental work on buildings, the contrast between the delicate pink of the sandstone and the pale blueish grey of the limestone is decidedly pleasing. Aghadoe House, Killarney, affords an excellent example. The house itself is built from the Glenbeigh quarries of old red sandstone, whilst the quoins, window-sills, &c., are of limestone from the Killorglin neighbourhood.

The chisel marks in the stone show as sharply to-day as they did when the house was built some 70 years ago—indicating that there has been practically no weathering, and demonstrating the excellent character of the finest old red sandstone for building purposes in the country.

When arranging for the metalling of any important road

it is necessary to use great care in the selection of a suitable stone, for upon this will depend to a large extent the annual bill for maintenance. Unfortunately the individual on whom the choice depends is not always in a position to put his hand on the best possible material; he has to use what he can get in the country through which his road passes. The material of which the soleing or lower layer of metal is composed does not so much matter, as it is not intended for wear and tear, and, so long as it fulfils its functions of affording a good sound bed and preventing any of the metal from slipping through, and being lost in the earthwork, nothing more need be expected or required from it, for those in charge of the maintenance should make it their duty to see that fresh metal is always put down in ruts, or where the surface of the road is being worn thin. No cart wheel should ever reach the soleing.

It may be roughly stated that any good sound stone or even *hard* slate broken in sizes about as large as an ordinary brick, or slightly smaller, will do very well.

Where brick kilns are numerous and extensive, there is usually a considerable quantity of clinker or over-burnt bricks which form an excellent substitute for stone in soleing. The colour of this is nearly always deep red, and where vitrification has been complete it is often black. Bricks which are thus over-burnt are of course almost indestructible from their extreme hardness, and the chief objection to their being used in the best masonry is that they are usually very misshapen or cracked.

That there should be no waste it is here suggested that all such over-burnt bricks as cannot be utilised in masonry should be used instead of stone in the *soleing*.

With regard to the top surface or true metal the case is very different. A hard heavy class of stone is required to withstand the constant wear and tear of many wheels and

hoofs. Such stone is found in the igneous rock formations. Trap rock and good quality of granite fulfil the conditions admirably, and both break into sharp angular nodules well suited to binding and forming a compact surface, when finally watered and rolled, with the heavy steam rollers which should be used to finish off the work. Soft sandstones and slaty shales are amongst the very worst kinds of stones, and should never—if it can be avoided—be used for the surface metal.

Limestone makes good binding metal, and the author has seen many excellent roads metalled with old red sandstone, which answers well enough, if of good quality, and where the traffic is not too heavy, and where the maintenance is well looked after. It must be remembered, however, that all sandstones, though often admirable for building purposes, are very apt to powder and blow off the road in dry weather, and turn into thick mud in wet weather where the wheel traffic is at all heavy.

If stone—say sandstone—is very plentiful close at hand all along the line of your road it will be cheaper to metal with that material than to incur the cost of carriage of a better quality of stone from a distance; for, though in the latter case you may get a better surface to start with, you will find that repairs are almost certain to be carried out with the local stone, and that, after a few years, you will have practically a sandstone road, and you will then feel that you wasted money on the original construction. Of course it goes without saying that the softer the metal the more sharply you should look after the maintenance contractors.

Where the bank runs across jheel or marsh land, and in all places where the banking is soft it will be better to have the soleing broken slightly larger than it is on the level or in the cuttings.

In the author's experience many very first-rate country roads have been run across swamps where the bog has been so soft and so deep that it has been impossible to cut down to the clay beneath, and in many such cases bundles of saplings have been freely laid down at right angles to the line of the road; large flat stones have been superimposed, and then the road has been made like an ordinary Macadamised road on the top of this apparently insecure substratum. In driving rapidly over such roads the traveller experiences a slight undulatory movement due to the absence of solid foundation and the elasticity of the road itself.

Whilst on this subject it may be well to emphasise the importance of measuring your soleing and metal in the stack alongside the road before allowing it to be spread. Without wishing to cast the slightest slur on sub-contractors who are often conscientious and incorruptible, the unpleasant fact remains that the man who has agreed to supply you with 600 cubic feet of soleing, and 500 cubic feet of metal, per 100 feet of roadway, is often tempted to save his money by giving you short measure for two or three chains of the portion he has contracted for. Always therefore measure up your soleing and metal before spreading—when it is once on the road you cannot properly measure it by any artifice known to science.

Many sub-contractors may prefer to break the metal before bringing it on site; others carry the rough stone from the quarries, and break it and stack it on the road side. Always leave these matters to the men themselves. They have agreed to supply so much soleing of such and such quality, broken to a specified size, at so much a hundred cubic feet, or so much metal on similar terms. Let them make all their own arrangements; all you want to know is that the material is according to specification, and that you have the quantity agreed to.

A good size for *metal* is fragments the longest diameter of which will pass through a ring 2½ inches in diameter. Some say 2 inches, others three, but 2½ inches is a very fair average size for metal.

In arranging with the sub-contractors it is better to put into the agreements as to metal "including spreading and rolling," so that they agree to quarry, carry, break (according to specification) so much soleing, and so much metal at so much per cent. cubic feet, that they stack the same for measurement by the engineer, and afterwards spread the same and contribute to the cost of rolling by steam roller.

There is then no difficulty, and no question can arise as to what allowance should be made for the cost of spreading and rolling.

When the soleing and metal has been spread, the centre of the road being always kept 6 inches or so higher than the sides, the rollers should begin rolling the sides, and afterwards the centre. The surface should be carefully and steadily watered during the rolling process until the earth or clay from beneath the soleing rises up and flushes the surface. It is a great mistake, but one which is often made to save time and secure a "surface" rapidly, to place earth or clay *on* the metal whilst the rolling progresses.

When the watering and rolling are continued until the muddy clay is actually pressed up by the weight of the rollers, you may be sure that the soleing and metal alike are completely bedded in clay like concrete, and this is what is required. When the heavy part of the rolling is finished a light sprinkling of fine river sand is much to be commended, as it adds an excellent finish to the road surface.

In concluding these notes on metalling, which are the outcome of the author's experience during the three years he was in charge of the Baramula-Srinagar road con-

struction, it may be remarked that in all roads where the stone has to be carried from long distances the greatest care should be taken in fixing the rates, which should be so adjusted as to allow a fair margin of profit for the contractors. There are many, more especially amongst the smaller men, who will offer to take on a short section at a ridiculously low rate, in the hope that something may turn up to their advantage if they once get "on the work." It is far more fair and kinder in the long run to refuse any such tenders. The author knows of one important road where the chief contractors made a fair profit on earthwork and masonry, but lost heavily on the metalling, simply because nearly all the stone, both for soleing and metal, had to be carried from long distances, partly by water and partly by carts. Over portions of this road the average lead was as much as 15 miles, and, what with exceptionally dry weather and consequent failure of canal routes, and the high rate charged for bullock carts, the contractors had often to pay double their rate before the metalling work was completed, and their difficulties were increased by the desertion of many sub-contractors who had taken up the work at a still lower rate.

Therefore, this fixing of rates is one which should not be decided on hastily or before all ballast pockets and quarries have been visited, and the cost of quarrying, breaking and carrying from the same to site carefully calculated.

Pavements.

When your road runs through a country much subject to high floods, and more especially where heavy banking has been much resorted to, there may be a chance of serious damage to the surrounding country unless some means are provided for allowing a very large volume of water to escape rapidly. (Fig. 5.)

For this purpose, and in addition to the ordinary cul-

verts, openings or syphons which have been constructed, it may be advisable to lay down what is called an "Irish bridge," ferrash (Ind.) or pavement. This is done by depressing the road level with a gradual slope, say 1 in 10, from the formation level nearly to the ground level, and paving the entire space and sides of slopes with brick on edge or stone (laid on edge). Of course the extent of such pavement must vary with circumstances and the site should be selected only after taking a series of careful levels and ascertaining the point at which the waters of a flood are likely to accumulate in greatest volume; this will probably be at a point where your embankment is the heaviest.

Then, again, these pavements may be most advantageously used in mountain paths and roads where small streamlets, &c., cross at uncertain intervals and cut up the road surface. Indeed it may be safely stated that this method of dealing with all small streams is preferable to drains and culverts beneath the road surface, as those latter are perpetually getting choked by sticks, stones, mud and other *débris* washed down the mountain sides.

In the construction of these pavements care must be taken that the surface is built slightly concave, and that it slopes gradually towards the edge of the road. Also let all the stones be laid on edge, and take care that the stones near edge of road are heavy and well laid, so as to resist the stones, heavy trees, &c., which roll down the mountain sides. It is better, in the author's opinion, to have no pucca masonry in work of this kind on a mountain road. Good dry masonry is the best for several reasons. It is difficult to "scamp" dry masonry, as a glance will suffice to see if the headers go well back into the work, and if the stretchers are well laid. What is termed "unskilled" labour will carry out such work, and repairs are easily executed when damages have occurred.

FANS.

It often happens that very considerable difficulties are presented to the engineer by a stream debouching from a narrow gorge or canon and spreading out into a fan-like sheet or series of small streams. Instances of such obstacles are to be found in most countries where the mountains are steep, and melting snows cause heavy floods at certain times of the year. (Fig. 6.)

Say, for example, that the direction of the road is from A to B, and that the continuation of the line is at C, across the fan. Very possibly the small streams a, b, c. d, e, f, will be quite dry, with one or two exceptions, for by far the greater portion of the year; at other times they may be roaring torrents, or the extent of the flood may be such that the entire fan is one sheet of turbid water. Or again, at uncertain intervals the nullah and fan may both be cleared out by an avalanche of snow and ice, carrying with it huge trees and boulders. In such a case as this it is worse than folly to attempt the construction of any substantial bridge. No ashlar masonry or iron work, even were such expensive work permissible, however strong and good, could possibly resist such natural forces, and there are several ways of dealing with the question. The first is the construction of a pavement from B to C, over which the torrents or avalanche may harmlessly pass, or by bridging the narrow part of the nullah at D with a temporary, cheap bridge, and diverting the road in the curve B D C. By the former, which may not inaptly be called the "humouring method," because no resistance is offered, the pavement may, if really well constructed, last for years, and will merely require cleaning up a bit after each flood. In the second instance you make up your mind to lose an inexpensive bridge once or twice a year, and, of course, all

these questions will have to be considered if you are preparing a maintenance estimate.

In the above remarks it has been assumed that the water is fordable over the pavement at those times of year, but many nullahs exist where the sides are very steep and the point D is either quite inaccessible or unsuited for a bridge site, where also one, two or three of the streams are always deep and rapid and must be bridged. If we were dealing with a railway there would be no help for it, and though the wisdom of running a line of rails across so dangerous a spot might be more than doubted, a trestle bridge or viaduct would have to be built and the piers protected in the most approved manner; but as we are only considering a road, it will, to the author's thinking, be nearly always advisable to zigzag down the cliff at A, cross such streams as may exist with strong and rough timber bridges, and then zigzag up the other side at C.

In such cases as the above the engineer's judgment and skill will be put to a severe test. We never know, for example, that the configuration of nullah beds will be the same for two consecutive years; indeed, it may be safely said that in a country of forests and avalanches it is quite the exception to find the true bed of the stream unchanged after the annual floods. The reason for the change is often this:—High up in the mountain gorges—perhaps four or five thousand feet up—a tree may fall across a small rivulet, *changing its course,* or the same result may happen through an avalanche. The water in this stream must go somewhere, and the fact of its having to work out a new channel brings into existence a new set of conditions which ultimately result in the changes below and the destruction of the engineer's work.

The author has often seen strong masonry bridges built with the most careful attention to good principles completely

swept away—"scooped out" is more expressive—by a flood which instead of taking the arches took the abutments in the rear and completely removed them, not a single vestige of any of the stones remaining to tell the tale that a bridge once stood there. Anyone who has been the eye-witness of a brown flood in the Himalayas, when the thick, roaring torrent carries down hundreds of huge forest trees per hour, and boulders weighing many tons are sent crashing and thundering down stream, as though they were marbles, will feel that it is rather a hopeless task opposing even the most solid masonry to such terrible forces. What happens as often as not is this:—A number of forest trees collect between the abutments or piers. These prevent the passage of others till there is a mass of forest timber accumulated on the upper side of the bridge. The waters then become piled up, as it were, the bridge is gradually submerged, and, unable longer to support the weight, gives way with a rush, and the pent up waters dashing along with increased force probably clean out every scrap of masonry down below the very foundations. The author's respect for large mountain rivers in high flood has been very great ever since the destruction of the Kohala and Domel bridges in the flood of 1893. The former was a suspension, 60 feet above the river bed, bridge over the Jheelum, which every one thought far beyond the reach of any flood, and the latter a handsome girder bridge higher up the river, where the Kishenjunga river joins the Jheelum river. In the latter case the heavy iron girders were carried down stream along with the boulders and other *débris*, and were twisted into every conceivable shape, and were of course useless except as old iron. The Kohala bridge was torn from its position, the suspension rods being left hanging to the towers at either side of the river.

Bridges.

From the above remarks it will be gathered that the less piers and projecting abutments are resorted to the better, in all cases where very heavy and rapid floods may be expected. Where the span is considerable—say over 200 feet—it will generally be better to throw a suspension bridge across the stream. The initial cost will possibly be heavy, but if the anchorage is in solid rock and the abutments on which the towers rest are well tucked away so as to offer no obstruction to the waterway, you will probably be safe. The question of anchorage is of course a very important one, and for details reference may be made to the excellent articles on Suspension Bridges in "Trautwine."

For spans of 100 feet or less wooden bridges of the cantilever type are to be recommended in all places where timber is easily obtained, and, therefore, cheap. In such cases, and if the abutment sites are undeniably good and solid, and there is plenty of good large building stone about, dry stone abutments may be safely used, and have this advantage over mortar masonry—that the embedded ends of the timbers are less likely to rot. Such bridges as these are much used in Kashmir (Fig. 7), and they are extremely easy of construction, do not require what is called "skilled" labour, and, if washed away, are replaced at a comparatively trifling cost. If large stones are not plentiful it will be better to construct the abutments of timbers notched together horizontally at their crossings—after the fashion of a timber-crib—and then steadied by gravel or ballast filling.

Though uniformity is desirable on a road, utility should always comes first. As in the case of building a house the primary object is to secure a comfortable place to live in,

so with the road the first thing to be thought of is efficiency for the traffic expected over the road. Do not, therefore, ever hesitate about putting in a bridge of different type if you consider it is more suitable for the situation. Remember also that, as in the case of a chain, the strength of which is necessarily measured by the strength of the weakest link, the general efficiency of the road may be greatly interfered with by the breaking down of a bridge or the occurrence of an extensive slip. In mountain roads, however, as frequently hinted before, it will generally be advisable to make small bridges of timber, because if carried away they can be easily and quickly replaced. To facilitate repairs, &c., it will be well to have timber stacked near the bridge site for sudden emergencies; be careful, however, to place the stacks well out of reach of floods.

Landslips.

It would be easy to devote much time to the discussion of the various methods of dealing with slips, and to an interesting and instructive citation of cases in which those methods have been tried, either with or without success. There is, perhaps, no question which ought to be so carefully studied, as the selection of an alignment comparatively free from slips will insure a great annual saving in maintenance.

In this paper the space is so limited that it will only be possible to mention a few cases, and offer certain suggestions both as regards choice of alignment and treatment of unavoidable slips.

Roughly speaking, slips may be classed under two headings—wet and dry. The former often take place where the cutting has been through loose conglomerate, and the latter whether the angle of the mountain is very severe and

composed of slaty shale or collections of rolling boulders, and it is hardly necessary to say that in the northern hemisphere the wet slips are oftenest found on those sides of a valley which face north, and the dry on the slopes having a southern aspect, exposed to the rays of the sun for a longer time each day.

Having decided, more or less roughly, the most suitable alignment, it will be well, before definitely fixing on it, to examine most carefully all doubtful places, and to go to some expense in borings, &c., and to make all the inquiries possible from the inhabitants. You have also to remember that though a place may rest securely enough at a very steep incline *if let alone*, the fact of cutting a roadway through it alters the conditions and, as it were, invites and encourages a slip. It may often be well worth while, even in a case where an otherwise excellent alignment has been suggested, to contour or zigzag several hundred feet higher up to a level well out of reach of the lower level, in which there may be two or three ugly places to tackle.

For example, in the sketch No. 8 it would have been far preferable to cut the road at the point P at the top of the slip than to cut it in the middle of the slip, as at A B. Then, again, the action of a river or mountain torrent at the toe of the slip, M, may be constantly a source of trouble; each year fresh portions are eaten away, and at last the crash comes and the road disappears into the river. There are few matters connected with road engineering that cause more vexation and annoyance than clearing hopeless slips and making fresh cuttings through clay, sand or mud, which you know will all slip away before the next year. In the case of wet, loose conglomerate—which is clay and mud mixed with boulders of all sizes and shapes—what happens is this:—The rains having continued for some time, the clay becomes thoroughly satu-

rated, loses its cohesive properties, and is, moreover, increased in weight. There is then nothing to prevent its slipping down, which it does, carrying the road down with it. The worst of it is, too, that the "angle of repose" is hardly ever reached in these cases. The writer has constantly come across cases of wet slips at angles varying from 5° up to 45°. The mass is surcharged with water, and being often very little thicker than pea-soup will not stand at any angle, and will, of course, slide away over the smooth, rocky backbone of the mountain side.

Many proposals have been made and suggestions offered for treating such slips, all of which are more or less unsatisfactory. Prevention is better than cure, and therefore make every effort, on starting work, to avoid such places altogether; but of course you may find yourself engaged in maintaining a road in the construction of which you had no hand, or possibly passing through the slip is absolutely unavoidable.

One rather good plan is to cut boldly a deep vertical drain, right through the slip from top to bottom, which you will cross by a bridge at A B (see sketch No. 9). Into this drain a number of smaller ones will be run at angles, as shown, and there is a chance of by this means keeping the body of the slip dry. As long as you can succeed in doing this the slip will probably not move. Care must be taken to keep all the drains well cleaned up or the work will have been in vain. Melting snow is about the worst enemy confronting the engineer in his dealings with wet slips, for it soaks into the ground quicker than it runs off by the drains, and thus saturates the earth before the drains can fulfil their functions.

Then there is the method of groins, running much in the direction of the smaller side drains in the sketch; to make these successful many piles will have to be driven in,

and the spaces between interlaced with saplings and bushes, &c.

A third plan is to plant the slips with trees or shrubs having long tap-roots, and a combination of this with the first-named system of drainage may possibly be the most paying method to adopt.

Then, again, there are some engineers who recommend the judicious introduction of concrete walls both in wet and in dry slips, but it is to be doubted whether this plan can be universally recommended. In all engineering work common-sense, combined with experience and a sort of intuitive perception of the requirements of the case, must be the guide. No two cases are quite alike, and it must be left to the perspicacity of the engineer to decide on what to do in doubtful cases. Doctors disagree, and so do engineers, often upon points which to an outsider appear to be quite clear. The differences of opinion usually arise from the extreme difficulty of getting at a satisfactory and clear diagnosis. The data are not well-defined, and the forces of nature, like the causes which bring about those ailments to which flesh is heir, act in an unexpected manner, and often at the most unguarded points.

The object of these remarks has mainly been to emphasise the extreme importance of avoiding doubtful ground, even if in so doing an augmentation of initial cost is incurred. It must be remembered that slips such as have been alluded to are nearly always found near the foot of the mountains. In ages past possibly there was earth and mud all over the mountain. As years went by that which was originally between D, the summit, and C (Fig. 10), a point, say, half way down, has slid down and rested at an angle more or less acute, between C and A, the toe of what now constitutes a slip. If practicable the road should not be built at any point between A and C, but somewhere

between C and D, where the solid backbone of the mountain will afford a perfectly secure and satisfactory foundation. It need hardly be pointed out that these remarks apply with tenfold force with regard to railways, with their expensive permanent way and rolling stock and costly maintenance. The slipping down of half a mile of tonga road may not involve very serious loss, but were a similar catastrophe to befall the same distance of metals the loss would be considerable.

There are probably few better examples of mountain roads, in which almost every conceivable difficulty has had to be faced, than the Jheelum valley and Gilgit roads, which run through the dominions of the Maharajah of Kashmir between Rawal Pindi and Gilgit. Slips of all kinds, cuttings, through rock and hard conglomerate, galleries, bridges, often over extremely difficult places, and tunnels. The road, for the entire distance between Kohala and Baramula, a distance of about 95 miles, runs on the left hand bank of the river Jheelum, and, this being the shady side of the valley, retains the snow longer, and there are consequently many wet slips which give endless trouble every year. Many engineers are of opinion that the right hand bank should have been originally selected; probably the better plan would have been to run the road on the left hand bank, as it is now, but far higher up the mountain sides, *above* all the bad slips. This example is here introduced because it offers so many instances of the class of slips to which allusion has been made.

Retaining Walls.

A good retaining wall may effectually deal with a small local slip, but, needless to say, it is quite useless if its foundations rest on the slip being dealt with. Many of the most satisfactory walls—both face and retaining—are

made of the best dry masonry; for this class of work when the stones procurable are of large size, and are well bonded, allows the filtration of water which is apt to accumulate when first-class mortar masonry is used. Dry walls constructed like the sketch (No. 11), with a good batter, stepped at the back and with a secure foundation of width of from one-half to one-third the vertical height of the wall, may stand for ever, and the writer knows of many such which have lasted for eighty years and more.

In a country where stone is plentiful it is generally well to make your retaining walls of dry masonry, and to be careful to have the bedding courses running at right angles to the face of the wall, and not horizontally, as so many are improperly built.

The latter will vary with the degree of stability of the material to be supported.

The following description of the Baramula-Srinagar road is taken from the "Pioneer" of October 30th, 1896:—

"On the 26th and 27th instant the final inspection of this important work took place and the road was formally handed over to the State Engineers by Mr. R. G. Allanson-Winn, of the firm of Spedding & Co., who has had charge of the construction from start to finish.

"For many years past the want of a really good road between Baramula and the capital has been felt, but it was not till the latter end of 1893 that the State sanction was given and the work commenced.

"Early in October of that year Mr. Winn started a large number of sub-contractors on the earthwork, employing Kashmiris and Poonch men chiefly on the banks and Pathans on the heavy cuttings. The total completed earthwork has run up to 14,000,000 cubic feet, and a very large portion of this amount is in heavy banks across jheels

or rice-fields. In the following year, 1894, the masonry was put in hand, and brick-burning was commenced all down the line, the earthwork and collections of soleing and metal being simultaneously carried on. During this year, 1894, the work was much hampered and interfered with by the opposition of certain native officials, and it is only fair to say that a considerable loss of time was occasioned by frivolous and vexatious objections to necessary work. This interference continued into 1895, but gradually died away as the work approached completion. . . . . .

"One of the chief difficulties in connection with this work—a difficulty almost as serious as the opposition above alluded to—has been that of carriage of material. When the floods were out the ghats were of course nearer the road site, and the cost of carriage, being by boat, was much lessened, but when the water was low the carriage by cart became very expensive, and very little, if any, profit could be made on the rates allowed to the contractors.

"Great care has been taken to have only the best materials used in the masonry, and it is satisfactory to know that, as far as bricks and mortar are concerned, nothing very much better could be produced. Here again the question of carriage proved troublesome, for of the 167 bridges and culverts only seven are what can be called important works, and arrangements for small detached jobs at considerable distances apart are nearly always more costly and difficult to supervise than arrangements for the same quantity of work at one site. All the bridges appear to be strong, and they should practically last for ever, unless they are shaken by the earthquakes which often visit this country.

"The heaviest work on the road was the carriage and consolidation of the metal. In places where the bank is of a sandy nature the surface of the road kicked up and much

of the work had to be gone over again at considerable extra expense. Three steam rollers were employed, but unfortunately one of these came to grief in August and was placed quite *hors de combat* by a collision caused by the carelessness of one of the drivers.

"The entire length of the road, just under 33 miles, is divided by Messrs. Dhanjibhoy into six stages—the first is from Baramula to Dilna, a pretty little village quite close to the Jheelum's banks. In this stage the traveller should not fail to notice the Kanaspura Ziarat, which is to be seen amongst lofty trees on the right-hand side of the road, about 3½ miles from Baramula. On leaving Dilna one drives through Sangrawan village, and then on to the gap at Choorah and over the Ningle Bridge, in which there is some of the heaviest masonry on the line. A little further on Bulgam is reached, and here the horses are changed—completing the second stage. From Bulgam to Puttan some very interesting country is passed through, including the ruins of Tarpur and the villages of Khamayar and Pulhalan, at which latter place one sees, on the right-hand side of the road, a solitary giant deodar tree, which is one of the chief landmarks in that part of the country. At Puttan, which may be regarded as the half-way house, the third stage is completed and the traveller will often find time to admire the magnificent chinar trees, under which Mr. Winn's camp was pitched for over two years, and also to visit the ruins of two ancient Hindu temples which are still in fairly good preservation, notwithstanding the number of earthquakes which must have shaken them during their centuries of existence.

"The next stage is from Puttan to Haratrat, where the river is spanned by three fine arches; the only villages passed on this stage are Burn, where, oddly enough, many lakhs of bricks were burned, and Hanjvera (where there is

a considerable jheel which gave a good deal of trouble in the road construction) and Singpora.

"On leaving Haratrat the tonga keeps near the river bank till Meergand is reached. Here there is a small rest-house and some magnificent trees; also a jheel on which the sportsman may safely look for a big bag of duck in cold weather.

"A couple of miles further on Lawapura is reached, and this is the point where the old road to Gulmarg branches off. At a little place called Chack the horses are again changed for the final stage into Srinagar. In this last stage there is not much to notice, except the fine poplar trees which line the road the whole way to the city."

The roads upon which he has been employed having differed so widely in character, considerable scope has been afforded to the author for the acquisition of experience both in construction and maintenance work. It has also been his privilege to carry out these works for the most part in a fine climate, and surrounded by the grandest and wildest scenery in the world; and he hopes on a future occasion to be permitted to read a paper to this Institution which will be illustrated by a large number of photographs, and will contain fuller details than it has been possible to introduce into this brief sketch.

Mr. Moore said he had great pleasure in proposing a vote of thanks to the author for his paper. Of course the paper dealt principally with road-making which was subjected to different weather than they were accustomed to. Their works had never to stand floods that rose sixty feet. Six feet was a respectable flood in this country. He never could make out why the paved floors mentioned by the author should be called "Irish bridges." Perhaps the Saxon who gave them this name thought that everything

was upside down in this country. In olden times the Irish people made their floors with hurdles, and then when they took to building bridges they were so fond of the hurdles that they used them in the construction of the bridges also. There was another matter which the author had alluded to, and that was the abominable practice of putting such large quantities of mud on the top of the stones in the making of the roads. Of course, a very smooth surface is produced at first, but after a while they get just as bad again. There is no doubt that the method referred to by the author of rolling till the clay came up from the bottom was much the better way.

Mr. Price said he had followed the paper with great interest. There were just a few points on which he did not exactly agree with the author. Where he refers to roads across swamps he says "that bundles of saplings have been laid down at right angles to the line of road." It was the custom in this country to use them both at right angles and longitudinally. They found it worked out better either on roads or railways. Then the author spoke about putting in large, flat stones. In this country they did not use stones for boglands. They used gravel and peat, and then laid their road on that. He thought heavy stones would be liable to work themselves into the bog. With regard to the steam-rolling—this was a subject in which they were all very much interested at present. The author recommended rolling until the mud under the soleing rose up from the bottom and formed a concrete mass. In this country it was the custom when putting down soleing to lay the flat side of the stone down with a view to keep the mud at the bottom. He thought their experience as road engineers was that the mud was too liable to come out at the top, and they always endeavoured to keep it down below. They differed in their mode of construction in this

country. The author did not touch very much upon the depth of the metal for the second layer. He (Mr. Price) was accustomed to put over the soleing a coating of stones of about 4 inch nodules.

The PRESIDENT said the paper dealt principally with roads in India, and naturally they were very different to the roads in this country. The author said that a road with a gradient of 1 in 35 was about the steepest slope allowable for trotting horses. He was sorry to say that was not the standard in this country, where they found roads with a gradient of 1 in 10. They had some roads where cyclists were obliged to dismount and push their machines up the hill. He remembered once where a railway company were making a road, and he was prevented from asking them to reduce the proposed gradient of 1 in 10 because just a short distance from the place there was an existing road with a gradient of about 1 in 11. One in 35 would be a luxurious road. In this country the average road was about 1 in 22, and this was considered very good.

With reference to the construction of bridges and their waterways, this was an important matter. He remembered once having to construct a bridge, and he had no idea as to what size the bridge should be made, or what quantity of water would flow under it. He received such varying information that he was puzzled as to what size to make it. He then received the advice to go down the river and see the size of the nearest bridge and make his according to that. He did this and it worked out very well. Of course this would not work out very well if there was no bridge further down.

The author had mentioned about 60° arches in spans from 4 feet to 10 feet. In bridges of these short spans he

would recommend the use of the patent expanding metal with horizontal tubes filled with concrete. His experience of these was that they were very effective, and very much cheaper than the arched bridges for small spans.

With reference to the shape of the road surface, his experience was that whatever shape the road first assumed it would always take that shape. No matter what quantity of metal they put on the road in the hope of altering its shape the road would eventually wear itself into the first shape. Therefore it was important that the first shape should be as perfect as possible.

With reference to the side drains—catchwater drains—this was very important. Many years ago he was told there were three things to be considered in road-making. The first was drainage, the second was drainage, and the third was drainage. As his informant had said, the reason the roads were better in summer than winter was because they were generally dry then. If they could keep their roads dry always then they would always have good roads. Of course there was the danger of having them too dry, but there was no doubt that it would very much improve a road to have it well drained. It was very important to see what stones could be got in the locality of the works. But great care was necessary in the examination of the stones. He was in Kilkenny once, and while looking for ferns he came across a beautiful red stone; it looked an excellent stone, but when he went on a little further he found that the owner was quarrying these stones and leaving them exposed to the sun, the action of which was sufficient to convert them into powder. There was a great difference of opinion as to whether the Telford method or the Macadam method of road-making was the best. He had tried both, and found it hard to say which was the best. He was rather inclined

to favour the broken stones. He considered they should be broken to about 2½ inches, and that they should have a proper soleing. With regard to roads across bogs—there was no doubt that the roads across the bogs were the best roads in Ireland. They had the advantage of having no fences or hedges along their sides.

With regard to the steam-rolling, he thought if they forced the mud up from the bottom it was sure to be a good job if they shaped the road to the correct form to start with.

About the "Irish bridges," there were some of these in the mountainous districts in the West of Ireland. There was one in Achill Island which was very effective, and had been in existence for a great number of years. He remembered having a good deal of trouble with a bridge on the road between Westport and Clifden. It was washed away twice, and his reputation was beginning to suffer. As a last resource he went up the height and built a buttress and some groynes, and diverted the scattered bodies of water into one course. He regulated it so that it was discharged further down the river, where there was a bridge with three arches, and which was able to stand the full flood of water. With regard to the cantilever bridges, the mention of these bridges being used in India recalled to his mind what he had read, that this system of constructing bridges was used in China 500 years ago. This was a very long time before the Forth Bridge was constructed. He thought the modern cantilever bridge was nothing more or less than an extension of these old bridges.

The making of the retaining walls with dry masonry was an excellent thing. But they should always be careful to make outlet channels for the water to get through, so that it would not lodge behind them.

MR. ALLANSON-WINN, in reply, said:—With regard to Mr. Price's remarks about the steam-rolling, they found the result of rolling the roads until the mud came up from the bottom was very satisfactory. Some parts of the road required different treatment from other parts, as one part was soft, another sandy, and another hard. It was not all uniform. In some places they had great difficulty in getting a good surface, especially in the soft parts, and where sand predominated. In these places the soleing was about 6 inches and the metalling 4½ or 5 inches. It was very necessary to keep a sharp watch on the contractor or they would not roll until the mud came up from the bottom. It had to be insisted on in these roads, and the results proved it was the best method. Of course, on other roads different conditions might prevail, and other methods might be better. On this particular road they first laid the soleing, then the metalling was carefully spread to template. This was then rolled, with plenty of water put on, beginning at the sides and then the middle until they got the road into a barrel shape, exactly to template, and experience showed that the surface formation was satisfactorily maintained.

With reference to Mr. Price's remarks as to the laying of the bundles of saplings or faggots in boggy country, it might, no doubt, be well to lay some of the faggots parallel to the line of road, but it was far more important to lay them at right angles to the line of road, as by that means a better or *wider* bearing surface was secured.

REPORT OF COUNCIL FOR 1898.

THE numbers of Members and Associates at the close of the present as contrasted with the previous year are:—

	Members	Associates
In December, 1898 - -	138	85
In December, 1897 - -	144	89

The Council have still to urge on the Members the great desirability of increasing the numbers of Papers to be brought forward at the meetings held on the first Wednesday in each month during the Session.

The Council having determined to erect an additional room at the rere of the Lecture Hall have entered into a contract with Messrs. S. H. Bolton & Sons for the erection and completion of same for the sum of £420, which contract is now being actively carried out.

The revision of the Bye-Laws has had the serious consideration of the Council for some time past, and they hope in the next Report to be able to state that the new Bye-Laws will have received the sanction of the Members of the Institution, and also that it will be found that they will further the best interests, as well as raise the status, of the Profession in Ireland.

The Council again lay before the Members and Associates the great importance of their contributing more numerous Papers for the Sessional Meetings, as, in addition to the advantage to the Profession in Ireland, such Papers render the yearly volume of the Transactions valuable to the Profession at large.

The Council acknowledge with thanks the following con tributions to the Library of the Institution:—

"Railway Construction," presented by the author, W. H. Mills, Past President of the Insitution, also a number of

volumes on scientific and professional subjects from Mr. J. H. Ryan, Vice-President. All such contributions tend to render the Library valuable as a reference one to the Members and Associates. The Council hope at an early date to issue a complete catalogue of the Library.

The Council announce with regret the deaths of Sir Wm. Anderson, K.C.B., Past President; B. F. Flemyng, S. W. Haughton, Henry Johnston, James Kelly, W. J. Doherty, and W. G. Strype, Members.

The following Prizes have been awarded by the Council:—A Mullin's Silver Medal to E. W. Stoney for his paper on "Railway Construction in India." A Smith Testimonial Premium to Doctor W. E. Adeney for his paper on "Sewage Sludges."

The Statement of Accounts is appended, by which it will be seen there is a balance in favour of the Institution on the year's working.

The Council during the year were obliged, after repeated applications, to strike off the Register for non-payment of arrears of Subscriptions the following Members and Associates:—

Henry Tipping Crook.
Maurice A. Hennessey.
Gustavus Newenham Kelly.
John Lionel Lyster.
Arthur Irwin Mahon.
Michael Joseph M'Mullen.
Richard Newman Somerville.
J. Angelo Fahie.
John M. S. Green.
James O'Toole.
Frederick E. S. Pakenham
John Simpson.

AUDITORS' REPORT.

TRINITY CHAMBERS, 40 & 41 DAME-STREET,
DUBLIN, 13*th February*, 1899.

THE COUNCIL OF THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND, DAWSON-STREET, DUBLIN.

GENTLEMEN,—We have completed the Audit of your Accounts for the year ended 31st December, 1898, and send herewith certified Revenue Account and Balance Sheet made up to that date.

We have checked the major portion of the Receipts with the counterfoils issued by the Institution, and have seen vouchers for all the items of Expenditure.

The Income exceeded the Expenditure by £164 3s. 6d., but, by a Resolution of the Council dated 23rd March, 1898, it was decided to write off Subscriptions in arrear and considered to be irrecoverable to the extent of £115 11s. 6d., thus reducing the surplus to £48 12s.

We have vouched the Cash in Bank by an examination of the Pass Book.

The particulars of the Liabilities of the Institution have been furnished to us by the Assistant Secretary.

Your obedient servants,

CRAIG, GARDNER & CO.

THE INST

EXPENDITUR

To Printing, Stationery, and Sta
Due this date .

Less due 31st December

„ Sundry Expenses for General

„ Salaries, Wages, Fuel, and L
Less due 31st Decembe

Less payable by Photo
Society of Ireland

„ Painting and Repairs .
Due this date .

Less due 31st Decembe

„ House Rent and taxes .
Due this date .

Less due 31st December

„ Insurance . . . .
„ Audit Fee, &c. . .
„ Balance, being Surplus of In
diture . . . .

„ To Subscriptions in arrear
coverable . . .
„ Amount to Balance Sheet

THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

BALANCE SHEET, 31*st December*, 1898.

ASSETS.		£ s. d.
To Subscriptions in arrear—		
Members	£129 13 0	
Associates	70 7 0	
Students	9 0 0	
	209 0 0	
Less paid in advance £3 3 0		
Written off . 115 11 6		
	118 14 6	
		90 5 6
„ The Mullins' Bequest, £1,172 8s. 3d., 2¾ per cent. Consols		1,172 8 3
„ Smith Testimonial Fund, £97 14s. 7d. 3½ per cent. India Stock		97 14 7
„ India 3 per cent. Stock		149 15 3
„ Photographic Society, due for light		7 17 0
„ Rents receivable, due		125 0 0
„ Dividends due		9 13 3
„ Cash at credit of the Institution of Civil Engineers of Ireland in Royal Bank	£420 9 1	
Less cheques not presented	15 11 8	
		404 17 5
„ Premises, 35 Dawson-street, held under lease for 200 years from 1892, subject to £105 per annum, and Taxes		—
„ Library, including records of past proceedings		—
„ Furniture		—
Total, £		2,057 11 3

LIABILITIES.		£ s. d.
By Sundry Creditors—		
John Falconer	£3 3 4	
John Forster	22 14 3	
Maguire & Gatchell, Ltd.	5 2 4	
Welsbach Incandescent Light Co.	1 3 0	
Anderson & Co.	0 6 5	
Printing Transactions due	30 0 0	
Rent due	26 5 0	
		88 14 4
„ Surplus at 31st December, 1897	1,920 4 11	
Add amount from Revenue, &c., to 31st December, 1898	48 12 0	
„ Total Surplus to credit of Institution on 31st December, 1898, exclusive of value of Premises, Library, and Furniture		1,968 16 11
Total, £		2,057 11 3

We have examined the foregoing Revenue Account and Balance Sheet, and compared them with the Books and Vouchers of the Institution, and found them to agree, and to be correct.

DUBLIN, 13*th February*, 1899.

CRAIG, GARDNER & Co., *Auditors*.

REPORT OF COUNCIL FOR 1899

THE numbers of Members and Associates at the close of the present year as contrasted with the previous year are:—

	Members	Associate Members	Associates
In December, 1899 -	138	18	63
In December, 1898 -	138	—	85

The Council have pleasure in stating that the Annex to the Lecture Hall has been satisfactorily completed by their Contractors, Messrs. S. H. Bolton & Sons, under the supervision of Mr. W. W. Wilson, Past President, and Mr. Thomas Forsyth, Associate Member, to both of whom the marked thanks of the Institution are due for designing and preparing the plans and estimates, also special thanks to both Messrs. W. W. Wilson, and Edward Glover for their subscriptions of £50 and £10 respectively towards the cost of carrying out the above contract.

This Annex the Council hope to furnish as a Library and Writing Room, which they consider will afford an accommodation long wished for by the members and others connected with the Institution.

The Council regret the great falling off in the contribution of Papers, which prevented many of the meetings taking place during the Session, but they trust that during the coming Session Members, Associate Members, and Associates will contribute Papers on some of the many new and interesting subjects to which the attention of the Profession is now directed, both in Electrical Engineering and the best modes of carrying out the various Sanitary and other improvements likely to be adopted in towns of limited size by the

County Councils, under the provisions of the Local Government Act which came into operation in March of this year.

The Council also are pleased to report the completion of the amending of the Bye-Laws, which amendments were, as stated in the opinion of Mr. W. Jellett, Q.C., in accordance with the Charter, and by which they created a new class for Corporate Membership, namely—Associate Members, which the Council consider will enable a number of Pupils who have either completed their Pupilage, or have passed out from one of the recognised Engineering Schools, to join the Institution as Associate Members, thus enabling them to come in contact with. and be recognised as Members of the Profession at an early stage of their career.

The Council announce with regret the deaths of Richard Boyse Osborne, of Philadelphia, U. S. A., and James Tighe, Engineer of Waterford and Limerick Railway.

The Statement of Accounts is appended, duly certified as correct by the Institution's Auditors, Messrs. Craig, Gardner & Co.

AUDITORS' REPORT.

TRINITY CHAMBERS, 40 & 41 DAME-STREET,
DUBLIN, 27*th April*, 1900.

THE COUNCIL OF THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND, DAWSON-STREET, DUBLIN.

GENTLEMEN,—We have prepared the Accounts of the Institution for the year ending 31st December, 1899, and enclose certified copy of the Revenue Account and Balance Sheet.

The Income is derived from Subscriptions, Rents, and Interest on Investments. We have seen counterfoils of

the Receipts issued to all Subscribers; we have traced that the Rents out of the holdings have all been accounted for; and we have seen that the Dividends on the Investments have been received and charged. In addition to the foregoing an exceptional amount of £50 appears amongst the Receipts during the year, being a donation by the President towards building a new Hall.

We have seen vouchers for all the items of Disbursements, and a reference to the Account shows that the Expenditure exceeded the Income to the extent of £250 10s. 11d. for the year. This arises through a large sum having been spent on the new Hall already referred to.

Arrears of Subscriptions, amounting to £11 9s., have been written off as irrecoverable.

The amount of Arrears outstanding at the close of 1899 was £171 11s. Of this £66 3s. accrued up to 31st December, 1898. The Council should go carefully through these arrears, and either insist on payment, or, if they are irrecoverable, have them written off the Books.

We have inspected Certificates from the Bank of Ireland for the Consols and India Stock.

We have vouched the Cash in Bank by an examination of the Pass Book.

The Liabilities of the Institution have been supplied to us by the Assistant Secretary, who assures us that the list contains the entire indebtedness thereof.

Yours faithfully,

CRAIG, GARDNER & CO.

THE INST

EXPENDITU

To Printing, Stationery, and St
Due this date .

Less due 31st Decemb

„ Sundry Expenses for Genera

„ Salaries, Wages, Fuel and L
Less payable by Photo
Society to this date

Add amount 31st Dec.

„ Painting and Repairs
Due this date .

Less due 31st Dec., 189

„ House Rent and Taxes
Due this date .

Less due 31st Dec., 1898,
Proportion Taxes
paid in advance

„ Insurance . .
„ Audit Fee, Cheque Books, &
„ Cost of Building New Hall in
Lane , .
Due this date .

„ Balance brought down
„ Subscriptions in arrear writte

THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

BALANCE SHEET, 31*st December*, 1899.

ASSETS.			£ s. d.
To Subscriptions in arrear—			
Members		£106 11 6	
Associate Members		21 10 6	
Associates		50 8 0	
Students		4 10 0	
		183 0 0	
Less Subscriptions in advance	£6 6 0		
Amount to be refunded	0 10 6		
Written off	11 9 0		
		18 5 6	164 14 6
„ The Mullin's Bequest, £1,172 8s. 3d., 2¾ per cent. Consols			1,172 8 3
„ Smith Testimonial Fund, £97 14s. 7d., 3½ per cent. India Stock			97 14 7
„ India 3 per cent. Stock, £135 4s. 6d.			149 15 3
„ Rents receivable due			126 13 4
„ Dividends due			9 13 3
„ Photographic Society, due for light			8 5 11
„ Proportion of Corporation Taxes, paid in advance			8 8 4
„ Cash in Royal Bank of Ireland		£70 18 6	
„ Checks not presented		13 17 3	57 1 3
„ Premises, 35 Dawson-street, held under lease for 200 years from 1892, subject to £105 per annum and Taxes			—
„ Library, including records of past proceedings			—
„ Furniture			—
Total, £			1,794 14 8

LIABILITIES.		£ s. d.
By Sundry Creditors—		
Samuel H. Bolton & Sons	40 13 6	
Maguire & Gatchell	7 11 8	
John Falconer	1 18 6	
Arthur Hamilton, Rent	26 5 0	76 8 8
„ Surplus at 31st December, 1898	1,968 16 11	
Less amount from Revenue Account, being excess of Expenditure over Receipts	250 10 11	
„ Total surplus to credit of Institution on 31st Dec., 1899, exclusive of value of premises, library, and furniture		1,718 6 0
Total £		1,794 14 8

We have examined the foregoing Revenue Account and Balance Sheet, and compared them same the Books and Vouchers of the Institution, and found them to agree, and to be correct.

REPORT OF COUNCIL FOR 1900.

THE following is a comparative statement of the number of Members at the close of the year 1900, and the preceding one respectively:—

		Members.	Associate Members.	Associates
December, 1900	-	138	24	63
December, 1899	-	138	18	63

The Council are glad to note an improvement in the contribution of interesting papers, which improvement they trust will be maintained during the remainder of the Session, and thus tend to make the records of the Proceedings of value to the country members of the Institution.

The Council would again urge upon the Members, Associate Members. and Associates the great necessity of their endeavouring to write even short Papers upon the Engineering subject with which they may individually be brought in contact.

The Council acknowledge with thanks contributions to the Library of 12 Vols. "Wellington's Dispatches," presented by Mr. W. W. Wilson, Past-President; also 2 Vols. "Nouveau Portefeuille de Ingénieur des Chemins de Fer," (Perdonnet), and a number of German Engineering publications, presented by Mr. A. D. Price, Member.

The Council are pleased to record the success which attended the Institution Banquet, held on 18th April, 1900,

in the Gresham Hotel, and at which over 70 Members and guests were present.

It is desirable that the members of the Institution should be reminded that during the Session dinners are held at the Shelbourne Hotel, and that members contributing one guinea, which covers the cost of the dinners, are entitled to dine on the dates of the Sessional Meetings, which will be published at the beginning of each Session.

The Council have much pleasure in bringing under the notice of the Members and Associates of the Institution the fact that they have in progress the furnishing of the Annexe to the Lecture Hall as a Library and Reading Rooom, and they hope to have it ready for use before the termination of the Session. They trust this will meet a long-felt want—viz., a suitable room which the Members and Associates can make use of for reading or consulting purposes, and that both town and country members will show their appreciation of the provision made for them in this respect by largely availing themselves of its advantages.

The Council regret to record the deaths during 1900 of the following Member and Associates:—

Mr. Richard Barnsley Sanders.

Mr. John Holmes.

Mr. John Forster.

The Statement of Accounts for year ending 31st December is appended, from which it will be seen that the Institution is financially in a good position. At the same time the Council would specially ask the Members and Associates to forward their annual subscriptions on the 1st of January in each year to enable them to further the interests of the Institution, by maintaining the Library, and in other ways as they may consider advisable.

The Council have to record the pleasure they had, on

behalf of the Institution, in presenting an Address of Welcome to Her Majesty Queen Victoria on her visit to Ireland in April, 1900, which Her Majesty was pleased to most graciously reply to through the Right Honourable Sir Matthew White Ridley, Home Secretary.

The Address and Reply will be found in this Volume of the Transactions. (Page 5).

		Fr.
		d.
		0

BALANCE SHEET made up to 31st December, 1900.

ASSETS.	£ s. d.	£ s. d.
To Subscriptions in Arrear—		
Members	113 8 0	
Associate Members	16 5 6	
Associates	59 17 0	
Students	5 0 0	
	194 10 6	
Less Subs. in advance for 1901	2 2 0	
		192 8 6
„ The Mullins' Bequest, £1,172 8s. 3d., 2¾ per cent. Consols		1,172 8 3
„ Smith Testimonial Fund, £97 14s. 7d., 3½ per cent. India Stock		97 14 7
„ India 3 per cent. Stock, £135 4s. 6d.		149 15 8
„ Rents receivable, due		127 13 8
„ Dividends on Investments due		9 10 6
„ Proportion of Rates paid in advance		9 0 0
„ Cash in Hand—Bank £167 5 6		
Less Cheques unpresented	11 6 6	
	155 19 0	
Secretary	1 11 6	
		157 10 6
„ Premises 35 Dawson-street, Dublin, held on lease for 200 years from 1892, subject to annual rent of £105 and taxes		—
„ Library, including records of past proceedings		—
„ Furniture		—
Total, £		1,916 1 3

LIABILITIES.	£ s. d.	£ s. d.
By Sundry Creditors—		
John Falconer	10 12 5	
Maguire & Gatchell	19 13 8	
Major Bligh (per A. Hamilton) Rent	26 5 0	
		56 11 1
„ Surplus at 31st Dec., 1899—		
As per last Balance Sheet	1,718 6 0	
Subscriptions for 1899 revived	1 11 6	
	1,719 17 6	
„ Surplus Income for 1900 from Revenue Account	139 12 8	
„ Total Surplus to credit of the Institution on 31st December, 1900, exclusive of value of Premises, Library, and Furniture, and before providing a Reserve against Subscriptions in arrear		1,859 10 2
Total, £		1,916 1 3

We have examined the foregoing Revenue Account and Balance Sheet, compared same with the Books and Vouchers of the Institution and found them to agree. We have made a detailed report to the Council under equal date, to which we refer.

February 5th, 1901.

CRAIG, GARDNER & Co., *Auditors*.

Publications received in exchange for Institution Transactions.

Engineering.	The British Architect.
The Engineer.	The Timber Trades Journal.
The Builder.	The Indian Engineer.
The Contract Journal.	Indian Engineering.
The Surveyor.	Caissier's Magazine.

Railway and Tramway World.

The Volumes of Transactions are exchanged with the following Institutions, &c. :—

American Academy of Arts and Sciences.	Boston.
American Society of Civil Engineers.	New York.
American Society of Mechanical Engineers.	New York.
Canadian Society of Civil Engineers.	Montreal.
Canadian Institute.	Toronto
Civil Engineers of Italy.	Rome.
Engineers' Association of New South Wales.	Sydney.
Engineers' Club of Philadelphia.	Philadelphia.
Franklin Institute.	Philadelphia
Institution of Civil Engineers.	London.
Institution of Mechanical Engineers.	London.
Institution of Engineers and Shipbuilders in Scotland.	Glasgow.
Institution of Junior Engineers.	London.
Liverpool Engineering Society.	Liverpool.
Midland Institute of Mining, Civil, and Mechanical Engineers	Barnsley
North of England Institute of Mining and Mechanical Engineers.	Newcastle
North Staffordshire Institute of Mining and Mechanical Engineers.	Stoke-on-Trent.
Nova Scotian Institute of Science.	Halifax, N. S.
Royal Engineer Institute.	Chatham.
Royal Institute of British Architects.	London.
Royal Scottish Society of Arts.	Edinburgh.
Royal Society of Antiquaries of Ireland.	Dublin.
Smithsonian Institution.	Washington.
Sociedad Cientifica Argentina.	Buenos Ayres.
Society of Arts.	London.
Société des Ingénieurs Civils.	Paris.
Surveyors' Institution.	London.
West of Scotland Iron and Steel Institute.	Glasgow.

Institution of Civil Engineers of Ireland.

ESTABLISHED 1835.

Incorporated by Royal Charter 1877.

BY-LAWS

As Authorised at General Meeting of Members, 29th March, 1899.

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BY-LAWS.

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INSTITUTION

OF

CIVIL ENGINEERS OF IRELAND.

BY-LAWS.

SECTION I.

OBJECTS.

1. The Institution of Civil Engineers of Ireland has been formed for promoting the acquisition of that species of knowledge which appertains to the professions of Civil and Mechanical Engineers.*

SECTION II.

CONSTITUTION.

1. The Institution of Civil Engineers of Ireland shall consist of Members, Associate Members, Associates entitled to the privileges of Corporate Membership, and Honorary Members. All Members, Associate Members, and Associates entitled to the privileges of Corporate Membership, may hereafter be referred to as Corporate Members. The Institution may also have attached to it Associates who are not entitled to the privileges of Corporate Membership, and Students.

2. Members shall comprise every person who on the 29th day of March, 1899, was on the Register as a Member; and

* To avoid misapprehension, Electrical Engineering shall be deemed to be included in Mechanical Engineering.

every person thereafter elected or transferred into the class of Members. Every Candidate for election or transfer into the class of Members shall be more than twenty-five years of age and shall come within one of the following conditions:—

(*a*) He shall have been regularly educated as a Civil or Mechanical Engineer, shall have had subsequent employment for at least five years, and shall be actually engaged at the time of his application for election or transfer, in responsible situations as Resident Engineer, or otherwise, in some of the branches constituting the profession of a Civil or Mechanical Engineer; or,

(*b*) He shall have practised on his own account in the profession of a Civil or Mechanical Engineer for at least seven years.

3. Associate Members shall comprise every person who, being a Civil or Mechanical Engineer by profession [evidence of which must be afforded to the Council, whose decision regarding such will be final], was on the Register as an Associate on the 29th day of March, 1899, and every person thereafter elected into the class of Associate Members.

Every Candidate for election into the class of Associate Members shall be more than twenty-one years of age, and he shall come within one of the following conditions:—

(*a*) He shall have been regularly educated as a Civil Engineer, shall have passed such examination or examinations as are recognised by the Council, and shall be actually engaged at the time of his application for election, in the design, or in the construction, or superintendence of such works as are comprised within the profession of a Civil, or Mechanical Engineer; or,

(*b*) He shall satisfy the Council that he has had a sufficient training, that he has been engaged for at least three years, and that he is actually engaged at the time of his application for election in the design, or in the construction, or superintendence of such works as are comprised within the profession of a Civil, or Mechanical Engineer.

4. Associates entitled to the privileges of Corporate Member-

ship shall comprise every person who, not being a Civil, or Mechanical Engineer by profession, was on the Register as an Associate on the 29th day of March, 1899.

5. Associates not entitled to the privileges of Corporate Membership shall be persons who are not Civil or Mechanical Engineers by profession, but who, by their connection with Science or the Arts, or otherwise, are qualified to concur with Civil or Mechanical Engineers in the advancement of professional knowledge.

6. Honorary Members shall be either distinguished individuals, whose position or attainments qualify or enable them to render assistance in the prosecution of engineering works; or persons eminent for science, and experience in pursuits allied to the profession of Civil, or Mechanical Engineers.

7. Students shall be persons not under seventeen years of age, who are, or have been, pupils of Corporate Members of the Institution, or who are Students of an Engineering School recognised by the Council, and who, in either case, have complied with the regulations as to the admission of Students, and who have the object or intention of becoming Civil, or Mechanical Engineers; and such persons may continue Students until they attain the age of twenty-five years, but not longer.

8. Any Member, Honorary Member, Associate Member, Associate or Student having occasion to designate himself as belonging or attached to the Institution, may state the class to which he belongs, according to the following abbreviated forms—viz., M. Inst. C.E.I., Hon. M. Inst. C.E.I., Assoc. M. Inst. C.E.I., Assoc. Inst. C.E.I., Stud. Inst. C.E.I.

9. The Officers of the Institution shall be the following:—A President, two Vice-Presidents, one Honorary Secretary, and eight other elective Members (being twelve persons in all), who along with the Past-Presidents shall constitute the Council to direct and manage the concerns of the Institution; the officers are to be elected annually, in manner hereinafter

directed. Members shall not be eligible to the office of President for more than two years in succession; on vacating the chair they shall become *ex-officio* Members of Council. Two of the elected Members of Council shall retire every year, but shall be re-eligible after one year has elapsed.

10. The President, two Vice-Presidents, and seven at least of the other elective Members of Council shall be from the class of Members; the other two elective Members of the Council may be from the class of Associate Members, or Associates entitled to the privileges of Corporate Membership.

SECTION III.

ELECTION AND EXPULSION OF MEMBERS, ASSOCIATE MEMBERS AND ASSOCIATES.

1. Any person desirous of being admitted into the Institution as Member, Associate Member, or Associate must be proposed and recommended according to Form (A) in the Appendix, in which the name, usual residence, and qualifications of the Candidate shall be distinctly specified, so that the Members and Associate Members may be enabled to judge of his eligibility. This Form must be signed by the proposer, who must be a Member of the Institution, and certify from personal knowledge of the Candidate, and by at least three seconders who shall be Corporate Members of the Institution, and two of whom at least must be Members, testifying to a full conviction of his qualifications.

2. The proposal so made shall be submitted to the Council, who, on approving the qualifications, shall determine the class for which the Candidate is to be presented for ballot. The Chairman of the Council shall sign the proposal, which shall be read at an Ordinary General Meeting of the Institution. Particulars as regards the name and address of the Candidate, and the name of his proposer, shall be previously sent to each

Corporate Member resident in Ireland at least seven days before being so read. The proposal to be then placed in some conspicuous situation, in the rooms of the Institution, until the Candidate is balloted for.

3. Any person whose proposal has been approved and read, as prescribed in Clause 2, shall be duly informed of it by letter (Form C), enclosing an engagement (Form D) to abide by the By-Laws if elected, and he shall not be put up for ballot until he shall have returned said engagement with his signature appended.

4. The ballot shall take place at the Ordinary General Meeting of the Institution next after the receipt of the engagement signed as specified in Clause 3. Members, Associate Members, and Associates entitled to the privileges of Corporate Membership only, to have the right of voting.

5. The proportion of votes for the election of any person shall be at least three-fourths of the number voting.

6. In case of the non-election of any person balloted for, no notice shall be taken thereof on the minutes.

7. Honorary Members shall be nominated by the Council, and submitted for approval to the Annual General Meeting.

8. The proposal for transferring any person from the class of Associate Members to the class of Members shall be according to Form (B) in the Appendix. This Form being subscribed by five Members, of whom three, at least, shall not be on the Council, shall be submitted to the Council, who, if they see fit, may make the proposed transfer.

9. Any Candidate duly elected into the Institution, or transferred from the class of Associate Members to the class of Members, shall be informed thereof without delay by letter, according to Form (E); and he must pay the admission fee, and annual Subscription for the current year [or the increased Subscription in case of transfer], within two months after the date of his election [*or transfer*], otherwise his election [*or*

transfer] shall be void; but the Council may, in special cases, extend the time.

10. Every individual elected, and having made the proper payments, shall receive the diploma of his election, and be considered as admitted into, or attached to, the Institution.

11. If any Member, Honorary Member, Associate Member, or Associate shall contumaciously disobey the By-Laws, Regulations, or Resolutions of the Meetings or of the Council, or by speaking, writing, printing, or otherwise advisedly do anything to the detriment of the Institution, or become engaged in employments which are inconsistent with the character of the class in which he is enrolled, he shall be liable to expulsion.

12. And in case the expulsion of any individual shall be judged expedient by five or more Corporate Members, and they think fit to draw up and sign a proposal for such expulsion, the same shall be laid before the Council for their consideration. And if the Council find good reasons for the proposed expulsion, they shall direct the Hon. Secretary to write, according to Form (F) in the Appendix, to the person who is proposed to be expelled, advising him to retire from the Institution. If that advice be not followed, the Council shall, at the earliest convenient period, call a Special General Meeting of Corporate Members for the purpose of deciding on the question of expulsion; and if the majority of those present at such Special General Meeting, provided that the number of those voting be not less than twenty, agree that such individual be expelled, the Chairman of that Meeting shall declare the same accordingly, and the Hon. Secretary shall communicate the same to the individual, according to Form (G) in the Appendix.

SECTION IV.

ADMISSION AND PRIVILEGES OF STUDENTS.

1. Students may be admitted by the Council (according to Form (J) in the Appendix), and they may remain Students of

the Institution at and during the pleasure of the Council until they attain the age of 25 years, when they shall cease to be Students.

2. Any person admitted as a Student shall be informed thereof by letter (according to Form (K) in the Appendix), stating that the first year's Subscription shall be paid within two months, otherwise the admission will be void. When the first Subscription shall have been paid he shall be entitled to attend the Ordinary Meetings, but not to vote at such Meetings, and to have the use of the Library (subject to such regulations as the Council may from time to time prescribe).

3. The Council may accord to Students other privileges, but subject to such terms, regulations, and restrictions as they shall from time to time prescribe.

4. No Student will be allowed to introduce a stranger into the rooms of the Institution.

SECTION V.

ELECTION OF OFFICERS.

1. At the Ordinary General Meeting in December, the Council shall present a list of persons whom they nominate as suitable for the offices of President, Vice-Presidents, Honorary Secretary, and other elective Members of Council, for the ensuing year. This list shall be the balloting list for the election at the Annual General Meeting.

2. At this election, Corporate Members may erase from the balloting list the name of any person or persons, and substitute others from the same class, leaving, however, not more than twelve names for the respective offices above enumerated. Such lists as contain a greater number than twelve names, or do not accord with these directions, shall be rejected by the Scrutineers. The list shall be presented in person at the Annual General Meeting.

3. Previously to the commencement of the balloting for Officers the Meeting shall choose two Corporate Members as Scrutineers, who shall receive the votes.

4. The Clerk, or any other persons necessary for conducting the business of the Institution, shall be appointed by the Council.

SECTION VI.

CONTRIBUTION TO THE FUNDS.

1. Each Member shall pay Two Guineas per annum, except those resident twenty miles or upwards from Dublin, who shall pay One Guinea and a Half per annum, and those resident out of Ireland, who shall pay One Guinea per annum.

2. Each Associate Member shall pay One Guinea and a Half per annum, except those resident twenty miles or upwards from Dublin, or those resident out of Ireland, who shall pay One Guinea per annum; and each Associate shall pay One Guinea per annum. The Subscription of a Student shall be Ten Shillings per annum.

3. Every new Member or Associate Member shall pay an Entrance Fee of Two Guineas, and every new Associate an Entrance Fee of One Guinea.

4 Any Member, Associate Member, or Associate may compound for his Annual Subscription by the payment of Twenty Guineas. Any Member, Associate Member, or Associate going temporarily abroad for at least two years, on giving notice of such intention, and not being in arear to the Institution, will not be required to pay his usual Annual Subscription, but shall, upon his return, be entitled to the rights of Membership or Association, as the case may be, upon again resuming payment of the usual Subscription, which, however, will not be required on the occasion of a merely temporary visit; but under these

circumstances, while not paying his Annual Subscription, he shall not be entitled to Papers, or Transactions published during his absence.

Any Member, Associate Member, or Associate on going abroad to reside permanently, having paid all arrears, may compound for Ten Guineas, and become Life Member, Associate Member, or Associate, as the case may be.

Any person residing abroad, and desirous of becoming a Member, Associate Member, or Associate, may be elected for life upon his paying a Composition Fee of Ten Guineas, and the usual Entrance Fee; and no person of this class is to be elected on any other conditions, unless in the class of Honorary Members.

5. All Annual Subscriptions are payable in advance, and are due on the 1st day of January in each year.

6. Any Member, Associate Member, or Associate who, on the 1st of March, has not paid the current year's Subscription, and is also in arrear for the previous year, shall be reported to the Council, who shall direct application to be made according to Form (H) in the Appendix, and, in the event of his continuing six months in arrear after such application, he shall [*ipso facto*] cease to be a Corporate Member or Associate of the Institution, and the Council shall have the power of erasing the name of the defaulter from the Register of the Institution; notwithstanding this, said defaulter shall be liable for arrears. [See Form (I).] Any Student whose Subscription is in arrear shall not be entitled to attend any Meeting, or have the use of the Library, and if the Subscription is four months in arrear he shall cease to be a Student of the Institution.

7. In the case of any Corporate Member who has been distinguished in his professional career, but who from ill-health, advanced age, or other sufficient cause does not continue to carry on a lucrative practice, the Council, if they find good reason for the remission of the Annual Subscription, may so

remit it; also they may remit any arrears which are due by such an individual.

8. No Subscription is payable by persons admitted during the last two months of the year, for that year, nor by Members, Associate Members, or Associates returning from abroad for permanent residence during the same period.

SECTION VII.

THE PRESIDENT.

The President shall be a person eminent as a Civil or Mechanical Engineer. He shall take the chair at all meetings of the Institution at which he is present, and shall keep order, and regulate the proceedings.

SECTION VIII.

THE VICE-PRESIDENT.

In the absence of the President it shall be the duty of one of the Vice-Presidents to act as President. But in case of the absence of the President and the Vice-Presidents, the Meeting may choose any Member of Council, or in case of their absence, any Member present, to act as President.

SECTION IX.

THE COUNCIL.

1. The Council shall consist of the President, the two Vice-Presidents, the Honorary Secretary, and eight other elective Members of Council, together with the Past-Presidents.

2. The direction and management of the concerns of the Institution are vested in the Council, under the control of the By-Laws, and Resolutions of the Special General Meetings of

Corporate Members, which have been duly entered on the minutes, and signed by the Chairman of such Special General Meeting.

3. The Council shall meet as often as summoned by direction of the President, or, in his absence, by direction of any two Members of Council, and at every Meeting three shall constitute a *quorum*.

4. All questions shall be decided in Council by vote, the Chairman having, in addition to his ordinary vote, a casting vote; but at the desire of any two Members of Council present, the determination of any subject, except one previously postponed, shall be postponed to the succeeding Meeting, and special notice shall be given thereof.

5. The Council shall draw up a yearly Report, which, with a copy of the Treasurer's Accounts, shall be circulated among the Members annually.

6. It shall be the duty of the Council to take every possible means for the advancement of the Institution; to make such regulations as they may consider expedient for properly conducting the business of the Institution; to take such action or measures as they may consider necessary, in cases of emergency and on the death or resignation of Officers; and to arrange for the publication of Papers read at the Meetings, abstracts of the discussions thereon, or of such documents as may be calculated to advance professional knowledge.

SECTION X.

THE HONORARY TREASURER AND AUDITOR.

1. The Honorary Treasurer shall be nominated by the Council, and shall be responsible for all money not invested belonging to the Institution.

2. No sum of money payable on account of the Institution,

amounting to ten pounds or upwards, shall be paid except by order of the Council.

3. The Accounts of the Honorary Treasurer shall be audited in the month of January, in each year, by a Chartered Accountant appointed by the Council, or [in the alternative] by two Members of Council, who shall be nominated by the Council for that purpose, and who shall sign the same when found correct.

SECTION XI.

THE CLERK OF COUNCIL.

1. It shall be the Clerk's duty, under the direction of the Honorary Secretary and the Council, to conduct the correspondence and business of the Institution; to attend meetings of the Institution, and of the Council; to take Minutes of the Proceedings of such Meetings; to read the Minutes of the preceding Meeting; to announce any Donations made to the Institution; to superintend the publication of such Papers as the Council may direct; and to have charge of the Library, and other property of the Institution, and to transact its ordinary business.

SECTION XII.

THE SESSION AND MEETINGS.

1. The Session of the Institution shall commence annually, in November, and may continue till the end of May, and it shall be in the power of the Council to protract the Session if it appear advisable.

2. The General Meetings of the Institution shall be as follows:—First, General Meetings of Members and Associate Members only to alter and establish By-Laws and Regulations. Second, the Annual General Meeting for the Election of Officers. Third, the Ordinary General Meetings. Fourth, Special

General Meetings. At every General Meeting the presence of at least ten persons qualified to vote shall be necessary to constitute a *quorum*.

3. The Annual General Meeting of the Institution shall be held early in December, and at it the Officers for the ensuing year shall be elected.

4. The Ordinary General Meetings shall be held on the First Wednesday in each month during the Session, at eight o'clock in the evening; it shall be, however, in the power of the Council to make such exceptions as may appear advisable. No new business shall be entered upon after ten o'clock.

5. The business of the Institution shall be conducted as nearly as possible in the following order:—

1. The minutes of the preceding Meeting to be read, and, if confirmed, signed by the Chairman.
2. Business arising out of the minutes to be entered on.
3. Candidates' proposal papers to be read.
4. Ballot for Candidates to be opened.
5. Donations to be announced and acknowledged.
6. Communications from the Council to be brought forward.
7. Postponed discussions to be continued, new communications to be read, and discussions thereon to be entered upon.

6. Corporate Members shall have the privilege of introducing strangers to be present at the Ordinary General Meetings of the Institution, on presenting them with an admission card having the names of both visitor and introducer written thereon.

7. No question shall be discussed, or motion made, at the Ordinary General Meetings relative to the direction and management of the concerns of the Institution; such direction and management resting entirely in the discretion of the Council, under the control of the By-Laws, and the Resolutions of Special General Meetings.

8. A Special General Meeting of Corporate Members may be called at any time by the Council for a specific purpose. And the Council are at all times bound to do so on a requisition of five Corporate Members, specifying the nature of the business to be transacted. But such Special General Meeting shall have no power to alter, revoke, or dispense with any By-Laws whatsoever, such power resting only with a General Meeting of Members and Associate Members.

9. A Notice shall be sent to those Corporate Members who reside in the United Kingdom, at least seven days before the time appointed by the Council for such Special General Meeting; and the Notice shall specify the nature of the business to be transacted; and no other than that business shall be transacted at that Meeting. All Corporate Members shall have the right to attend and vote; and Ten shall constitute a *quorum*.

SECTION XIII.

COMMITTEES AND LECTURES.

The Council shall have power to appoint Committees for the purpose of investigating specific subjects connected with the objects of the Institution. The Reports of such Committees shall be submitted to the Council previously to their being read to the Institution. They shall also have power to request and, if necessary, pay out of the funds of the Institution for Lectures to be delivered upon specific subjects connected with Engineering, by persons whom they may consider qualified, whether Members of the Institution or not, and they shall arrange for the publication of such Lectures if they consider it desirable to do so.

SECTION XIV.

ENACTMENT OF BY-LAWS.

1. The Council shall, when they consider it expedient to propose the enactment of any new By-Law, or the alteration or

repeal of any existing one, summon a General Meeting of the Members and Associate Members to decide on the same.

2. The alteration or the repeal of any existing By-Law may be recommended to the Council by any three or more Corporate Members of the Institution. On this recommendation the Council shall, if they think proper, summon a General Meeting of Members and Associate Members to decide on the same.

3. No new By-Law, or the alteration or the repeal of any existing By-Law, shall be proposed at any Meeting of the Institution, except in the manner herein described.

SECTION XV.

THE PROPERTY AND PUBLICATIONS OF THE INSTITUTION.

1. The property and effects of the Institution, of what kind soever, are vested in the Corporate Members for the time being, for the use of the body at large.

2. Every Paper, Map, Plan, Drawing, or Model, which may be presented to the Institution, shall be considered the property thereof, unless there shall have been any previous arrangement to the contrary; and the Council may publish the same in any way, and at any time they may think proper. But should the Council refuse or neglect to publish such paper or other communication within a year, the author thereof, on giving notice to the Council, shall be empowered to copy the same, and publish it as he may think fit. No other person shall publish any communication belonging to the Institution, without the previous consent of the Council given in writing.

3. The Library shall be open to all Members, Associate Members, Associates, or others, under such Rules as the Council may direct, when they shall have the right to peruse and inspect all Books, Papers, Plans, Maps, &c., belonging to the Institution, and to make copies and extracts therefrom, doing no injury to

the same; but none of the property of the Institution shall be taken out of their rooms without the sanction of the Council in writing.

SECTION XVI.

DONATIONS AND BEQUESTS.

1. The names of all persons who have presented any additions to the Library, or to the collections of Plans and Models, or who have made any voluntary contribution to the funds of the Institution, shall be recorded and published in the Proceedings.

2. Every person desirous of bequeathing to the Institution Manuscripts, Books, Maps, Plans, Drawings, Instruments, or other personal property, is requested to make use of the following form in his will:—

> "I give and bequeath to the Institution of Civil Engineers of Ireland (*here enumerate and particularise the effects or property to be bequeathed*), and I hereby declare that the receipt of the President and Honorary Secretary of the said Institution, for the time being, shall be an effectual discharge to my Executors for the said Legacy."

APPENDIX.

(A.)

A. B.
of being desirous of admission into the Institution of Civil Engineers of Ireland, I recommend him from personal knowledge, as a person in every respect worthy of that distinction, because

[*Here state distinctly the qualifications of the Candidate, according to the spirit of Articles* 2, 3 *and* 5, *Sec. II.*]

On the above grounds, I beg leave to propose him to the Council as a proper person to be admitted into the Institution.

Signed, Member.

Dated this day of 1

We, the undersigned, concur in the above recommendation, being convinced that A. B. is in every respect a proper person to be admitted into the Institution.

Signed,

The Council having considered the above recommendation, present A. B. to be balloted for as
of the Institution of Civil Engineers of Ireland.

Signed,

Chairman.

Dated this day of 1

Read to the Institution day of 1

(B.)

We, whose names are hereunto subscribed, submit to the Council of the Institution of Civil Engineers of Ireland the propriety of transferring A. B. of from his present class of Associate Members to the class of Members, because

[*Here state distinctly the qualifications of the Candidate, according to the spirit of Article 2, Section II.*]

Witness our hands, this day of 1

The Council of the Institution of Civil Engineers of Ireland meeting on the day of 1 transfer A. B. from the class of Associate Members to the class of Members.

Signed, Chairman.

(C.)

SIR,

I have the honour to inform you that, after having been proposed by Mr. M.Inst. C.E.I., and seconded by Messrs. your name was laid before the Council, who have recommended that you shall be elected to the class of of the Institution of Civil Engineers of Ireland, and the proposal was read to the General Meeting on day of I beg to transmit to you a copy of the Charter and of the By-Laws of the Institution.

Previously to your name being submitted to Ballot at the next General Meeting, you are required to sign and return the accompanying engagement.

I am, sir, &c.,

Hon. Sec.

(D.)

I, the undersigned, being proposed for Ballot as of the Institution of Civil Engineers of Ireland, do hereby promise that, if elected, I will be governed by the By-Laws of the said Institution as they are now formed, or as they may hereafter be altered, amended, or enlarged under the powers of the Royal Charter of the Institution; and I promise to promote the objects of the said Institution as far as shall be in my power, and to attend the Meetings thereof as often as I conveniently can. Provided that, whenever I shall signify in writing to the Hon. Secretary, for the time being, that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand, day of 1

(E.)

SIR,

I have the honour of informing you that on the day of you were duly made of the Institution of Civil Engineers of Ireland. According to the By-Laws, you are required to forward to the Treasurer within two months of the date of your election [*or transfer*], the sum of being otherwise your election [*or transfer*] will be void. This being complied with, you will be considered as a of the Institution, with the diploma of your election [*or transfer*], and any publication to which you are entitled will be forwarded according to your directions.

I am, &c.,

Hon. Sec.

(F.)

SIR,

I am directed by the Council of the Institution of Civil Engineers of Ireland to inform you that upon full consideration of a proposal which has been laid before them relative to you, they will call a Special General Meeting thereon, as is provided for by Section III., clause 12, of the By-Laws of the Institution enclosed. But previously to taking such a step it becomes the duty of the Council to inquire whether it be your intention to retire from the Institution.

I am, sir, &c.,

Hon. Sec.

(G.)

SIR,

It is my duty to inform you that by a Special General Meeting of the Institution of Civil Engineers of Ireland, which was held here on the day 1 according to the provisions of Section III., clause 12, of the By-Laws, you were declared to be no longer belonging to the Institution.

I am, &c.,

Hon. Sec.

(H.)

SIR,

I have to inform you that the fact of your being in arrear of your Subscription to the Institution of Civil Engineers of Ireland has been reported to the Council, who have directed me to apply to you therefor, and to notify that in the event of your continuing six months in arrear after this application, you cease to be a of the Institution, and the Council will exercise their power under Section VI., clause 6, of the By-Laws, of erasing your name from the Register of the Institution, and taking such measures as they be advised for recovering your arrears.

I am, &c.,

Hon. Sec.

Amount due, £

(I.)

SIR,

I have to inform you that in accordance with Section VI., clause 6, of the By-Laws of this Institution, and Form (*H*) already sent to you, your name has been removed from the Register by the Council.

I have also to inform you that you are nevertheless liable for the amount of your arrears, amounting to £

I am, sir,

Your obedient servant,

Hon. Sec.

(J.)

STUDENT.

A. B.

of

born on the day of 1 being desirous of admission as a Student of the Institution of Civil Engineers of Ireland, I recommend him, from personal knowledge, as worthy of that privilege, and as coming within the rules appertaining to that class—viz., that he is upwards of 17 and is under 25 years of age, and is—

[*The qualifications of the Candidate must be distinctly specified according to the spirit of Article 7, Sec. II.*]

[Signature of the proposer, who must be a Member or an Associate Member of the Institution.]

Signature of the Candidate.

Dated this day of 1

The Council having considered the above recommendation admit A. B. as a Student of the Institution of Civil Engineers of Ireland.

Signed,

Chairman.

Dated this day of 1

(K.)

SIR,

I have the honour to inform you that the Council of the Institution of Civil Engineers of Ireland, meeting on the day of 1 admitted you as a Student of the Institution.

According to the Regulations of the Institution you are required to pay the sum of , being the amount of your first Subscription, within two months from the date of your admission, otherwise the admission will be void. When such payment has been made you will be entitled to the privileges of your class.

I beg to point out that all Annual Subscriptions become due upon the 1st of January, in each year, for the year then commencing.

I am, sir,

Hon. Sec.

LIST OF OFFICERS AND COUNCIL,

YEARS 1899 AND 1900.

Institution of Civil Engineers of Ireland

Established 1835 (Incorporated by Royal Charter, 1877),

35 DAWSON-STREET, DUBLIN.

COUNCIL, 1899.

President:

W. W. WILSON.

Vice-Presidents:

EDWARD GLOVER.
JOHN HENRY RYAN.

Other Members:

WM. ANDERSON,
ROBERT COCHRANE,
LOUIS E. H. DEANE,
JOSEPH H. MOORE,
WM. PURCELL O'NEILL,
WILLIAM ROSS (*Hon. Treasurer*)
SAMUEL J. SHANNON,
PROSSER A. H. SHAW.

Past Presidents:

BINDON B. STONEY,
CHARLES P. COTTON,
ALEX. M'DONNELL,
WILLIAM H. MILLS,
JOHN A. F. ASPINALL,
JOHN P. GRIFFITH,
SPENCER HARTY,
THOMAS F. PIGOT,
JAMES DILLON.

Honorary Secretary:

MARMADUKE BACKHOUSE.

COUNCIL, 1900.

President:

EDWARD GLOVER.

Vice-Presidents:

WM. PURCELL O'NEILL,
JOHN HENRY RYAN.

Other Members:

WM. ANDERSON,
ROBERT COCHRANE,
JOSEPH H. MOORE,
WILLIAM M. MURPHY,
GEORGE M. ROSS,
WILLIAM ROSS (*Hon. Treasurer*),
SAMUEL J. SHANNON,
PROSSER A. H. SHAW.

Past Presidents:

BINDON B. STONEY,
CHARLES P. COTTON,
ALEX. M'DONNELL,
WILLIAM H. MILLS,
JOHN A. F. ASPINALL,
JOHN P. GRIFFITH,
SPENCER HARTY,
THOMAS F. PIGOT.
JAMES DILLON,
W. W. WILSON.

Honorary Secretary:

MARMADUKE BACKHOUSE.

LIST OF MEMBERS.

INSTITUTION
OF
CIVIL ENGINEERS OF IRELAND,

Established 1835 (Incorporated by Royal Charter, 1877),

35 DAWSON-STREET, DUBLIN.

1901.

COUNCIL.

President:
EDWARD GLOVER.

Vice-Presidents:
ROBERT COCHRANE, | JOHN HENRY RYAN.

Other Members:

WM. ANDERSON,	GEORGE M. ROSS.
ROBERT COEY,	WILLIAM ROSS (*Treasurer*)
JOSEPH H. MOORE,	SAMUEL J. SHANNON,
JAMES PRICE.	PROSSER A. H. SHAW.

Past Presidents:

BINDON B. STONEY,	JOHN P. GRIFFITH,
CHARLES P. COTTON,	SPENCER HARTY,
ALEX. M'DONNELL,	THOMAS F. PIGOT,
WILLIAM H. MILLS,	JAMES DILLON,
JOHN A. F. ASPINALL,	W. W. WILSON.

Honorary Secretary:
MARMADUKE BACKHOUSE.

Bankers:
ROYAL BANK.

Members are requested to inform the Honorary Secretary if any correction be necessary.

HONORARY MEMBERS.

(*Hon. M.Inst.C.E.I.*)

ELECTED		
1868 M 1882 H.M.	Grubb, Sir Howard, F.R.S., F.R.A.S., &c.	51 Kenilworth-square, Rathgar
1897	Cameron, Sir Chas. A., M.D., F.R.C.S.I. . . .	51 Pembroke-road, Dublin.

MEMBERS.

(*M.Inst.C.E.I.*)

1901	Allanson-Winn, Rowland Geo. A., B.A., Cantab.	22 South Frederick-st., Dublin, and Glenbeigh, Killarney.
1892	Alexander, *Professor* Thomas, M.A.I.	39 Trinity College, Dublin.
1898	Allen, Henry	Rehoboth House, South Circular-road, Dublin.
1869 F.L.A. 1875 F.L.M.	Apjohn, James Henry M.A., M.Inst. C.E., (*L.M.*)	Engineer, Port Trust, Calcutta.
1880	Armstrong, George Allman .	Timoleague and Courtmacsherry Light Ry., Bandon, Co. Cork.
1885	Armstrong, Robert Carew .	Umzinto, Alexandra Co., Natal.
1877	Aspinall, John Audley Frederick, M. Inst. C.E. (*L.M.*, *Past President*)	Lancashire and Yorkshire Ry. Works, Horwich.
1880	Backhouse, Marmaduke, M.A.I. (*Honorary Secretary*)	9 Harcourt-terrace, Dublin.

ELECTED		
1896	Barnard, Albert William . .	Ballyverane House, Macroom, Co. Cork.
1896	Barnes, Robert Stephenson .	Tatestown, Navan, Co. Meath.
1876 A 1879 M	Barnes, John Frederick Evelyn, M.Inst. C.E. (*F.L.M.*)	Maritzburg, Natal, South Africa.
1874 A 1880 M	Barrington, Edward . .	3514 N. St., N.W., Wash., D.C., U.S.A.
1865	Beatty, John	India.
1892	Bergin, Francis, B.E. . .	Beech Grove, Kildare.
1899	Bergin, John Philip . . .	D. W. & W. Ry. Co., Westland-row, Dublin.
1890	Berry, Joseph . . .	Town Hall, Kingstown, Co. Dublin.
1883	Birch, Edward Robert, Assoc. M. Inst. C.E. . .	Swilly-terrace, Buncrana.
1900	Brett, Henry Charles . .	19 Wellington road, Dublin.
1874	Brett, John H. (*L.M.*) . .	Co. Surveyor, Antrim; Belfast.
1895	Buckley, Michl. J. . . .	41 Rathdown-road, North Circular-road, Dublin.
1876 A 1883 M	Chappell, Henry . .	The Grove, Newtownards, Co. Down.
1895	Clarke, Eugene O'Neill . .	County Surveyor, Leitrim; Carrick-on-Shannon.
1865	Clark, George R. . .	
1870 A 1882 M	Cochrane, Robert, M.R.I.A., F.S.A., F.R.I.B.A. (*Vice-President*)	Board of Works, Dublin.
1888	Coey, Robert (*Member of Council*)	St. John's, Island Bridge, Dublin.
1890	Coffee, Francis R. . .	2 Eaton-terrace, Tramore

ELECTED		
1886	Comber, Patrick Forstall . . M. Inst. C.E., F.S.I.	19 Lower Leeson-street, Dublin.
1865	Cooke, Theodore, M.A. (*F.L.M.*)	Imperial Institute, London.
1861	Cotton, Charles Phillip, M.Inst. C.E. (*Past President*)	Ryecroft, Bray, Co. Wicklow.
1900	Cowan, Peter Chalmers, M. Inst. C.E.	Local Government Board, Dublin.
1860	Crawford, Robt., M.E., M. Inst. C.E.	Stonewold, Ballyshannon, Co. Donegal.
1883	Creery, Leslie, B.A.I. . .	Fortal, Killiney, Co. Dublin.
1881	Crowe, Oswald Byrne, B.A. .	
1892	Cusack, Henry Edward . .	M. G. W. Ry. Works, Broadstone, Dublin.
1884 A 1899 M	De Burgh, Ernest Macartney	Union Bank of Australia, Sydney, N.S.W.
1900	Dick, Fred. J., M. Inst. C.E. .	Board of Works, Dublin.
1863	Dillon, James, M. Inst. C.E., (*Past President*)	36 Dawson-street, and Stratford House, Glenageary, Co. Dublin.
1898	Dixon, E.K., M. Inst. C.E. .	County Surveyor, South Mayo; Castlebar.
1862	Dodd, George (*F.L.M.*)	
1888	Doyle, Patrick (*F.L.M.*), . M.R.I.A., F.R.S.	19 Lall Bazar, Calcutta.
1878	Duffin, William Edmund L'Estrange	County Surveyor, Waterford; Larkfield, Waterford.
1898	Fallon, Bernard N . . .	Netterville Lodge, Toomard, Ballinasloe.
1873 A 1899 M	Ferguson, William, B.E., M.A. M. Inst. C.E.	Harbour Board, Wellington, New Zealand.
1900	Fortescue, Matthew, . .	57 Grosvenor-road, Rathgar.

ELECTED		
1894	Fletcher, Francis Dudley . .	Shannon Navigation, Board of Works, Dublin.
1875	Geoghegan, Samuel . .	St. James' Gate Brewery, Dublin.
1888 A 1893 M	Gilcriest, William Fawcette	Wine-street, Sligo.
1877	Glover, Edward, M.A., B.E., M. Inst. C.E., F.R.I.B.A. (*President*)	County Surveyor, Kildare 19 Prince Patrick-terrace North Circular-road, Dublin.
1887 A 1892 M	Going, Shirley Russell (*L.M.*)	17 Nassau-street, Dublin, and 35 Sandycove-road, Kingstown, Co. Dublin.
1895	Gray, George David . .	36 Edenvale-road, Ranelagh, Co. Dublin.
1887	Greenhill, William . . .	Great Northern Railway, Dundalk.
1881 A 1886 M	Grierson, Thomas Benjamin, M. Inst. C.E.	15 Victoria-st., Westminster, London, S.W.
1871	Griffith, John Purser, M.Inst.C.E. (*Past President*)	Greenane, Temple-rd., Rathmines, and Port and Docks Office, East-wall, Dublin.
1898	Hargrave, Joshua Harrison, B.A., B.E. .	Great Northern Railway, Amiens-street, Dublin.
1875	Harty, Spencer . . . (*Past President*)	5 Trevelyan-terrace, Rathgar, and Engineer's Office, City Hall, Dublin.
1892	Hamilton-Smythe, Arthur James, M. Inst. C.E.	
1894	Haslam, William J., B.E. .	Eustace-st. Buildings, Dublin.
1896	Haycroft, James Isaac (*F.L.M.*)	Fontenoy, Ocean-st., Woollahra, Sydney, New Sth. Wales

ELECTED		
1894	Hellins, Henry Herbert .	City Hall, Dublin.
1872	Heenan, Robert Henry, M Inst. C.E.	Port Elizabeth, Cape Colony.
1887	Henderson, Ernest . . .	Canadian Pacific Railway, Smithfalls, Ontario, Canada.
1895	Hill, William Henry, junr. .	Audley House, Cork.
1897	Hurtzig, Arthur Cameron, M.Inst. C.E.	2 Queen Square Place, Westminster, London, S.W.
1882	Ivatt, Henry Alfred, M.Inst. C.E. (*Past Vice-President*)	Gt. Northern Ry., Doncaster.
1893	Johnston, George Leopold .	Armagh Sewerage Works, Armagh.
1901	Jolly, James	12 Belmont-road, Harrogate.
1877	Joyce, Arthur Edward, . .	County Surveyor, Westmeath; Ballinagore, Co. Westmeath.
1896	Keating, Wm. Johnson, B.E. .	28 York-road, Rathmines, Dublin.
1887	Kernaghan, William . . .	2 Hume-street, Dublin.
1883	Latimer, John	11 Denny street, Tralee.
1898	Leahy, James D. . . .	Newcastle West, Co. Limerick.
1889	Leask, Robert H. . . .	37 College-green, Dublin.
1901	Lilly, Walter Elsworthy . .	39 Trinity College, Dublin.
1856	Lyons, M. E. (*F.L.M.*) . .	
1884	Manning, William . .	Cookstown, Kells, Co. Meath.
1896	Martin, Frank V. (*L.M.*) .	82 North Wall, Dublin.
1898	Maunsell, Richard Edward Lloyd .	Mount Vernon, Inchicore, Dublin.

ELECTED		
1884	Maxwell, John Francis, M.A. .	Lisna Arran, Rostrevor.
1860	M'Donnell, Alexander, M.Inst. C.E. (*Past President*)	Rydens, Hersham-road, Walton-on-Thames.
1880	M'Donald, Donald . . .	Larne Harbour, Co. Antrim.
1882 A 1892 M	M'Mullen, James F. . .	30 South Mall, Cork.
1882	Metge, Peter Ponsonby . .	Clonmaskil, Delvin, Co. Westmeath.
1877	Mills, William Hemmingway, M.Inst.C.E. (*Past President*) .	Nurney, Glenageary, and Great Northern Railway, Dublin.
1862	Moberly, Charles Henry, M.Inst. C.E. (*F.L.M.*)	33 Bennett-park, Blackheath, London, S.E.
1869 A 1874 M	Moore, Joseph Henry, M.A.I., T.C.D. (*Member of Council*)	County Surveyor, Meath; 63 Eccles-street, Dublin.
1900	Moore, William P. . . .	3 Temple-street, Dublin, and Port and Docks Office, East Wall, Dublin.
1879 A 1882 M	Morony, Henry Vereker Lloyd, B.E., Assoc. M. Inst. C.E.	Harbour Commissioners' Office, Limerick.
1866	Morris, Thomas B., M. Inst. C.E.	Messrs. King, King & Co., Bombay.
1888	Morris, William Henry . .	Belfast and Co. Down Ry., Belfast.
1881	Moynan, John Ousley, M.A. .	Co. Surveyor, North Tipperary, Nenagh.
1888	Moynan, Joseph, B.E., Assoc. M. Inst. C.E.	Dundas Shire, Hamilton, Victoria, Australia.
1883	Mulvany, Christopher, M.A., B.E., M. Inst. C.E. .	County Surveyor, Roscommon; Athlone.
1882	Myles, Thomas Joseph, B.A., M. Inst., C.E. .	Engineer's House, M.G.W. Ry., Athlone.
1901	Montgomery, Henry Bevan Slator, L.C.E., T.C.D. .	5 Elgin-road, Dublin.
1878	Nugent, Samuel William . .	Martello House, Kingstown, Co. Dublin.

ELECTED		
1896	O'Neill, William Purcell . .	Edenvale, Conyngham-road, Island Bridge, Dublin. and Engineer's Office, M. G. W. Railway.
1887 A 1899 M	Ormsby, Charles Croasdaile	District Engineer's Office, M. G. W. Ry., Galway
1869 A 1876 M	Ormsby, Robert Daly, M.Inst. C.E.	Director of Public Works, Hong Kong.
1892 A 1898 M	O'Sullivan, John G., Assoc. M. Inst. C.E. .	2 Charleville-terrace, N.C.R., Dublin.
1888	Parry, William Kaye, M.A., B.E.	63 Dawson-street, Dublin, and 6 Charlemont-terrace, Kingstown.
1898	Parshall, Horace F. . .	8 Prince's-street, Bank, London, E.C.
1891 A 1891 M	Payne, Sinclair William .	Upton House, Cork.
1895	Perrott, William George, B.A., B.E., Assoc. M.Inst.C.E.	Montrose, St. Laurence-road, Clontarf.
1874	Pigot, Thomas F. (*Past President*)	14 Fitzwilliam-place, Dublin.
1897	Porter, Samuel . . .	27 Beresford-road, Oxton, Cheshire.
1897	Price, Alfred Dickinson, M.A.Ing., M. Inst. C.E. .	3 Fortfield-villas, Palmerston-park, and Local Government Board, Dublin.
1896	Price, James, M. Inst. C.E. (*Member of Council*) .	Engineer, Harbour Commissioners, Cork.
1865	Price, W. H., M. Inst. C.E. .	
1883 A. 1901 M.	Purcell, Marmaduke . .	62 Pembroke-road, Dublin.
1890	Robinson, John George . .	Gt. Central Ry., Gorton.
1874 A 1893 M	Ross, George Murray, M.A., B.E. (*Member of Council*)	63 Dawson-street, Dublin.

ELECTED		
1884	Ross, William, B.A.I., T.C.D. (*Member of Council and Treasurer*)	66 North Wall, Dublin, and Summerfield, Dalkey.
1893	Rowe, James Thomas . .	25 St. Andrew's-terrace, North Circular-road, Dublin.
1896	Ruddle, Mark	45 Londonbridge-road, Dublin.
1896	Ryan, John Henry, M.A., M.Inst. C.E. (*Vice-President*)	22 Nassau-street, Dublin.
1882 A 1887 M	Shannon, Samuel James, B.E. (*Member of Council*)	Claremont, Meath-road, Bray.
1881	Shaw, Prosser Austin Haynes, L.C.E., T.C.D. (*Member of Council*)	21 Clarinda-park, Kingstown, and St. James' Gate Brewery, Dublin.
1896	Smith, John Chaloner . .	Pier Works, Kilronan, Aran Island, Co. Galway.
1861	Smyth, John, M.A., F.C.S. .	Milltown, near Banbridge.
1881 A 1894 M	Smyth, Richard O'Brien . .	2 Kenilworth-square, Rathgar, and Local Government Board, Dublin.
1898	Spunner, Henry Francis .	18 South Mall, Cork.
1882	Stewart, Abraham M'Causland, B.E.	20 Ship-quay street, Derry.
1857	Stoney, Bindon Blood, F.R.S., LL.D., M.R.I.A., M.Inst.C.E. (*L.M., Past President*)	14 Elgin-road, Dublin.
1868	Stoney, Edward Waller, M.E., M. Inst. C.E. (*F.L.M.*) .	Chief Engineer, Madras Railway, Royapuram, Madras.
1873	Stoney, Robert Vesey (*L.M.*) .	Rosturk Castle, Co. Mayo.
1872	Stoney, Thomas Butler (*F.L.M.*)	Oakfield, Raphoe, Co. Donegal.
1880	Spence, William . . .	107 Cork-street, Dublin.
1891	Sutter, Charles H. N. . .	18 Carlisle-avenue, Donnybrook, Co. Dublin.
1844	Tate, Alexander (*L.M.*) . .	Longwood, Belfast.
1882	Thomson, Frank William, B.E.	

ELECTED		
1860	Tuthill, Robert Reeves . .	9 Mount Avenue, Ealing, London, W.
1893	Vereker, Henry Robert, F.S.I. .	Shevdilla, Westport, Co. Mayo.
1865	Waller, George Arthur, M.A. (*L.M.*)	Cangort Lodge, Hobart, Tasmania.
1862	Walpole, Thomas (*Past Vice-President*)	Windsor Lodge, Seafield-av., Monkstown, Co. Dublin.
1875	White, Henry Vincent . .	County Surveyor, Queen's Co., Ballybrophy.
1874	Willson, Frederick Richard Thomas, B.E.	Burnside, Buncrana, Co. Donegal.
1897	Wilson, John George . .	Kylasse, Chalvey Park, Slough, Bucks.
1875 A 1882 M	Wilson, W. W., M. Inst. C.E. M.R.I.A. (*Past President*)	Ardganah, Ball's Bridge, Dublin.
1876 A 1880 M	Wise, Berkley Deane, M.Inst. C.E.	Silverstream House, Greenisland, Belfast, and Belfast and Northern Counties Railway.
1871	Wright, John Arthur (*F.L.M.*)	Cadiz Water Works, Sto. Cristo 4, Cadiz.

ASSOCIATE MEMBERS.

(*Assoc. M. Inst. C.E.I.*)

1897 A 1899 A.M.	Acton, John Henry .	Civil Eng. Staff, East Indian Railway, Calcutta.
1895 A 1899 A.M.	Ashworth, Charles Herbert	42 Dame-street, Dublin.
1879 A 1899 A.M.	Barnes, Robert Samuel Wemyss, Assoc. M. Inst. C.E.	Durban Club, Durban, Natal, and 16 Balls-road, Claughton, Birkenhead.

ELECTED		
1900	Barnes, Robert Stephenson, junr.	Tatestown, Navan.
1888 A 1899 A.M.	Barry, William Fitzgerald, Assoc. M. Inst. C.E.	County Surveyor, Monaghan; Town View, Monaghan.
1900	Blake, John . . .	55 Lower Mount-st., Dublin.
1901	Crawcour, Chas. Edward Stuart	2 Washington-villas, Dargle-road, Bray.
1901	Colaco, Alinsio Leonard (*F.L.A.M.*)	9 Hornby-road, Fort, Bombay.
1896 A 1899 A.M.	Delaney, James . .	County Surveyor, King's Co., Tullamore.
1898 A 1899 A.M.	Dillon, J. Trevor . .	R. E. Office, Armagh.
1900	Douglas, Charles K. .	Rathmolyon, Enfield, Co. Meath.
1896 A 1899 A.M.	Evans, Richard . .	53 South Mall, Cork.
1896 A 1899 A.M.	Fitzgerald, Cecil Henry (*F.L.A.M.*)	Assistant City Engineer, Georgetown, Demerara, British Guiana.
1895 A 1899 A.M.	Forsyth, Thomas . .	5 Royal-terrace, Fairview, Co. Dublin.
1887 A 1899 A.M.	Gaffney, Francis Sebastian, Assoc. M. Inst. C.E.	Colonial Engineer's Office, Singapore, S.S.
1886 A 1899 A.M.	Hade, William Patrick .	Dublin-street, Carlow.
1896 A. 1901 A.M.	Harris, Herbert T. . .	30 Parliament-street, Dublin.
1900	Hurley, Hugh Stanislaus .	Rath Hurley, Ballylinan, Athy.

ELECTED		
1896 A 1899 A.M.	Jackson, James Thomas .	Royal Survey Dept., Ayuthia, Siam.
1900	Kennedy, John Aloysius .	18 Ailesbury-road, Dublin.
1901	Leask, Henry Norman .	18 Acomb-street, Manchester.
1890 A 1899 A.M.	MacGarvey, Howard .	Lombard-street Works, Dublin.
1894 A 1899 A.M.	Moore, George Tighe .	184 Gt. Brunswick-street, Dublin.
1880 A 1899 A.M.	Moyers, Sir George, LL.D. .	8 Vesey-place, Kingstown.
1896 A 1899 A.M.	Newbigging, John . .	City Hall, Dublin
1901	O'Sullivan, Patrick F. .	Tolka View, Richmond-road, Fairview, Dublin.
1900	Quigley, John. . .	Roscrea.
1897 A 1900 A.M.	Richardson, Thos. Henry	c/o Grindley and Groom, Calcutta.
1901	Sheehy, Bryan Edward Fitzgerald.	50 George-street, Limerick.
1893 A 1899 A.M.	Spence, Arthur Wm. .	11 Brighton-avenue, Rathgar, Dublin.
1901	Travers, Frank V. J. .	Butlerstown House, Timoleague, Co. Cork.
1890 A 1899 A.M.	Warren, George Gates .	

ASSOCIATES.

(*Assoc. Inst. C.E.I.*)

ELECTED		
1896	Allen, William Henry . .	Church-place, Ennis.
1884	Anderson, Wm. (*Member of Council*)	9 Upper Sackville-street, and Glenavon, Merrion-road, Dublin.
1896	Anthony, Ernest John . .	
1895	Auld, James Paton . . .	74 Middle Abbey-st., Dublin.
1896	Benson, William Arthur Sanders	Fort Barracks, Bloemfontein, Orange River Colony.
1895	Bingham, Charles H. . .	Messrs. Tedcastle, M'Cormick, & Co., Dublin.
1898	Bolton, Samuel H. (F.L.A.) .	c/o Messrs. C. H. Walker & Co., Casilla de Correo 796, Buenos Aires.
1887	Carson, James . . .	Belmont, Solihull, Warwickshire.
*1901	Clayton, Henry F. . . .	4 Woodville, Sandford-road, Dublin.
1896	Cuttriss, Alfred W. M. . .	R. E. Dept., Buncrana, near Londonderry.
1889	Deane, Louis E. H. . . .	Local Government Board, Dublin.
1887	Doran, Henry . . .	Tavrane House, Ballyhaunis, Co. Mayo.
1896	Espinasse, James . . .	9 Bridge-street, Portadown.
1883	Evans, James	27 Rutland-square, Dublin.
1874	Falkiner, Nathaniel L. . .	Port Chalmers, New Zealand.
1881	Fleming, Henry . . .	Chicago, U.S.A.

* Marked thus are Non-Corporate Associates.

ELECTED		
1887	Gaskin, James	Surveyor's Office, Exchange Buildings, Dundalk.
1885	Gill, Robert Paul	30 Castle-street, Nenagh.
1895	Gilcriest, John Fawcette	Wine-street, Sligo.
*1901	Gordon, C. W.	53 Northumberland-road, Dublin.
1879	Gray, William Armroyde	New York.
1898	Hargrave, William Harrison	78 Manor-street, Waterford.
1898	Harriss, George Marshall	Electricity Works, Carlow.
1896	Hewitt, Wm. Tyrrell O. B., F.R.G.S.	West Indian Club, Howard Hotel, Norfolk-st., London, S.W.
1897	Higginbotham, Fred. Wm.	9 Lr. Sackville-street, Dublin.
1896	Kelly, Cecil Fletcher	Johnstown House, Athlone.
1895	Lamon, Thomas W.	Newtownards, Co. Down.
1885	Maguire, William Robert	Tower Hill, Dalkey, and 10 Dawson-street, Dublin.
1867	Martin, Charles E. (*L.A.*)	82 North Wall, Dublin.
1888	Martin, John E., B.A., T.C.D. (*L.A.*)	82 North Wall, Dublin.
1890	Martin, Thomas P. (*L.A.*)	82 North Wall, Dublin.
1898	M'Cann, Walter	Town Surveyor. Drogheda
1895	M'Caw, George Tyrrell	Taghnevan, Lurgan.
1893	M'Kenzie, Colin Douglas	1 Governor-road, Strand-road, Londonderry.
1898	Morris, Ernest Horatio	43 Dame-street, Dublin.
1892	Mulville, Michael Walsh	William-st., Listowel, Kerry.
1881	Murphy, William M.	Dartry, Rathmines, Dublin.

* Marked thus are Non-Corporate Associates.

ELECTED		
*1900	Nolan, Edward P. . . .	The Quoile, Downpatrick.
1897	O'Kelly, W. H. . . .	Sion House, Glenageary, Co. Dublin.
*1901	O'Neill, Thomas J. . . .	19 Crumlin-road, Belfast.
1893	Owen, Charles Austin . .	29 Molesworth-street, Dublin.
1861	Patterson, Benjamin Thomas .	95 Lr. Leeson-street, Dublin.
*1899	Pilkington, Thomas Henry .	Glenard, Clare Castle.
1895	Phillipson, Burton R. . .	Calgarth, Dalkey, Co. Dublin.
1888	Power, James Talbot, D.L. (*L.A.*)	Leopardstown Park, Co. Dublin.
1895	Reinhardt, John . . .	Qui-si-sano, Newtown-avenue, Blackrock, Co. Dublin.
1887	Rochford, John . . .	4 Clarinda-park, West, Kingstown, and Board of Irish Lights.
1885	Ruthven, John Alexander Cameron	174 Gt. Brunswick-st., Dublin.
1892	Sandall, Walter . . .	
1892	Strong, James Henry . .	Hammond-lane Foundry, Dublin.
1892	Stuart, William Henry . .	Cloonamore, Ballaghadereen, Co. Mayo.
*1901	Tatlow, Joseph . . .	M. G. W. Ry., Broadstone, Dublin.
1887	Tresilian, Richard S. . .	9 Sackville-street, Upper, and Cumnor, Eglinton-road, Donnybrook, Co. Dublin.
*1899	Wakeman, Wm. James Perrin .	117 Cave Hill-road, Belfast.
1888	Wallace, Charles H. . .	35 Dame-street, Dublin.

* Marked thus are Non-Corporate Associates.

ELECTED		
1895	Wallace, James Nevin . .	
1887	Watson, Charles W. . .	Hollywood House, Princes-st. Melbourne, Australia.
1891	Whiteford, James . . .	11 Richmond Crescent, Antrim-road, Belfast.
1893	White, Ambrose . . .	
1867	Woodward, Richard Caleb - .	Brisbane, Queensland.
1881	Worthington, Robert .	40 Dame-street, Dublin.

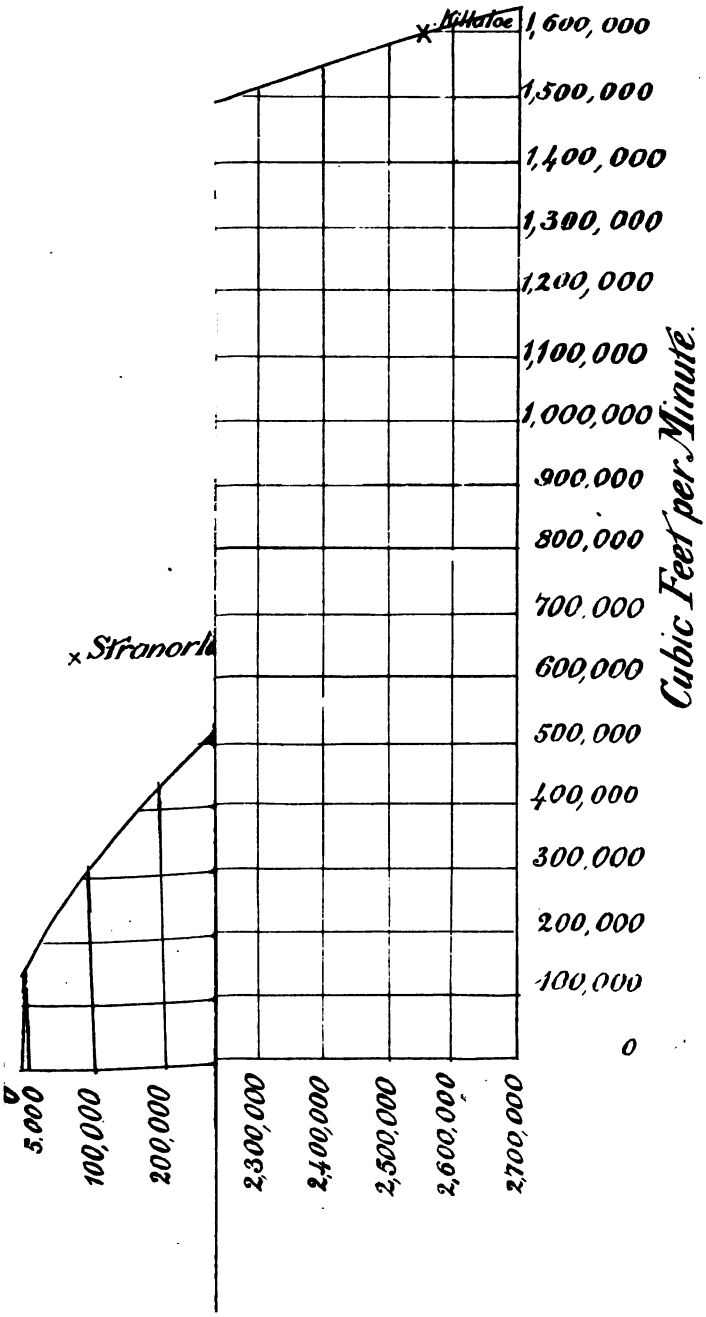
NOTE—*L.M., Life Member; F.L.M., Foreign Life Member; L.A.M., Life Associate Member; F.L.A.M., Foreign Life Associate Member; L.A., Life Associate; F.L.A., Foreign Life Associate.*

STUDENTS.

Baker, Lorenzo	Knole, Howth, Co. Dublin.
Brown, Vere Ward, junior . . .	Balnagowan, Palmerston-park, Rathmines, Dublin.
O'Callaghan, Francis	5 Alma-terrace, Monkstown, Co. Dublin.
Vickery, John Alfred	5 Ovoca-road, S.C.R., Dublin.
Wilson, Hezlitt Hamilton . . .	Ardganah, Ballsbridge, Dublin.

Printed by JOHN FALCONER, 53 Upper Sackville-street, Dublin

Curvd.


Killatoe
Stronorla
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1,500,000
1,400,000
1,300,000
1,200,000
1,100,000
1,000,000
900,000
800,000
700,000
600,000
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Cubic Feet per Minute.
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100,000
200,000
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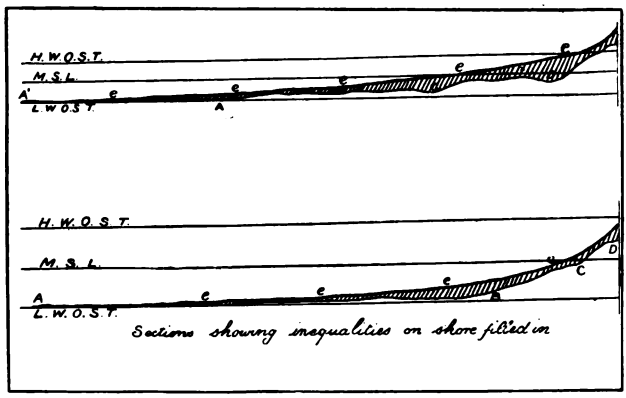
2,400,000
2,500,000
2,600,000
2,700,000

Fig. 1.

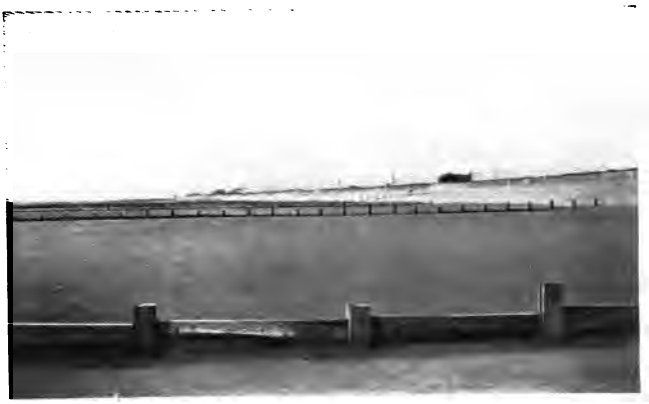


ACTION OF CASE GROYNES.

Fig. 2.

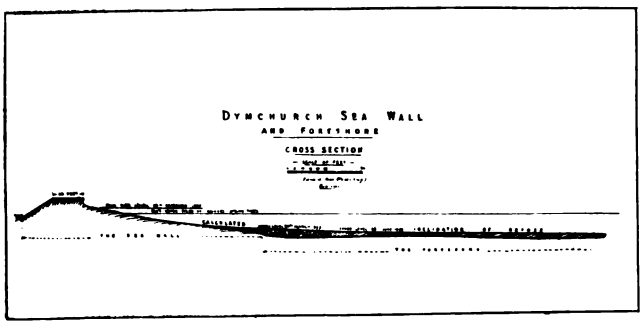
DYMCHURCH--BEFORE.

Fig. 3.



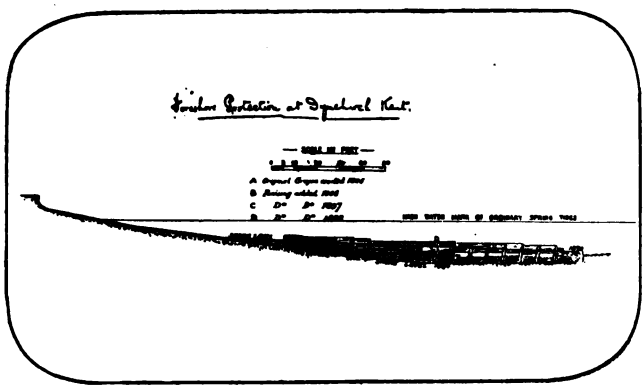
DYMCHURCH--AFTER.

Fig. 4.



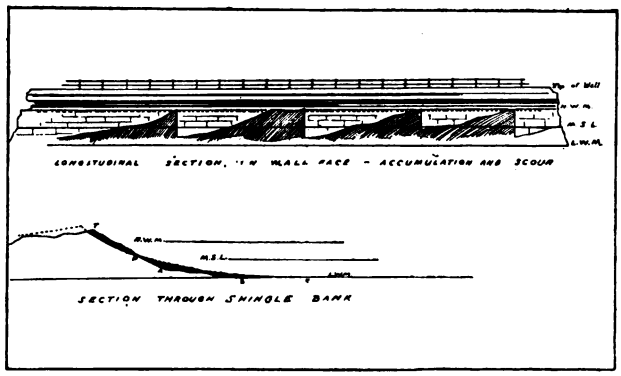
DYMCHURCH SEA WALL.--SECTION OF WALL AND SHORE.

Fig. 5.



METHOD OF RAISING GROYNES.

Fig. 6



ACTION OF HIGH GROYNES.

Fig. 7.

HASTINGS AND ST. LEONARDS.--DEEP SCOUR AT HIGH TIMBER GROYNE.

Fig. 8.

HASTINGS AND ST. LEONARDS.--DEEP SCOURS ON LEE SIDE OF SEVERAL OF THE HIGH GROYNES.

Fig. 9.

DEAL--BEFORE ERECTION OF CASE GROYNES.

Fig. 10

DEAL--AFTER ERECTION OF CASE GROYNES.

Fig. 11.

CROMER SANDS.--EXTENSIVE "SWILL" OR LATERAL CHANNEL.

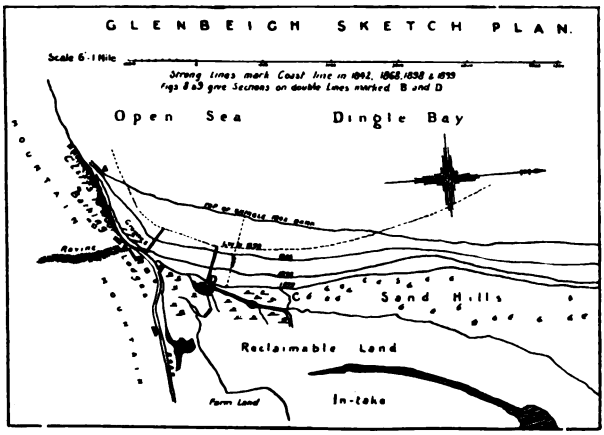
Fig. 12.

SWILL DIMINISHING THROUGH ACTION OF CASE GROYNE.

Fig. 13.

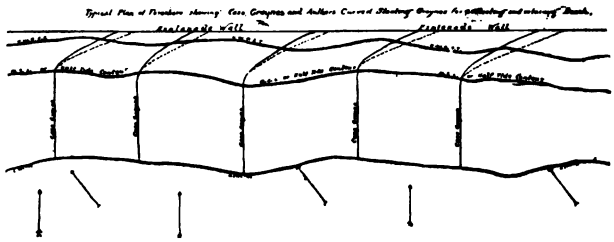
SWILL OBLITERATED THROUGH ACTION OF CASE GROYNE.

Fig. 14.



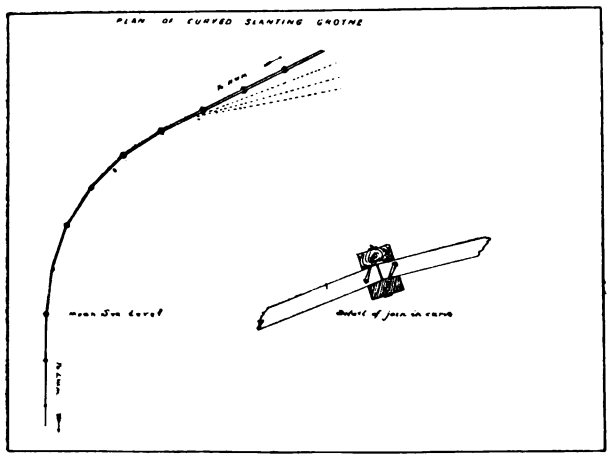
EXTENSIVE EROSION AT GLENBEIGH, CO. KERRY.

Fig. 15.



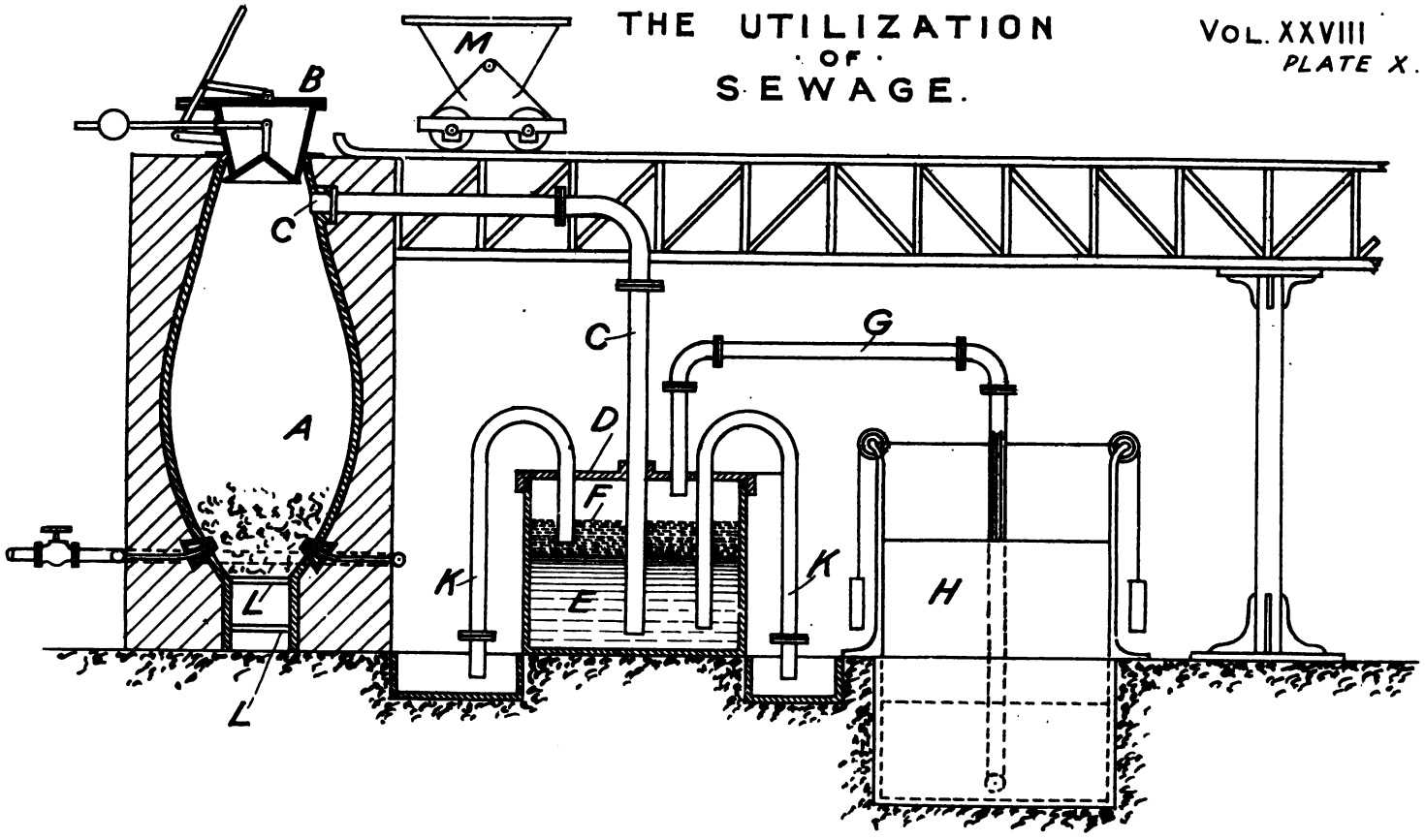
AUTHOR'S CURVED SLANTING GROYNES, JOINING ON LAND ENDS OF CASE GROYNES.

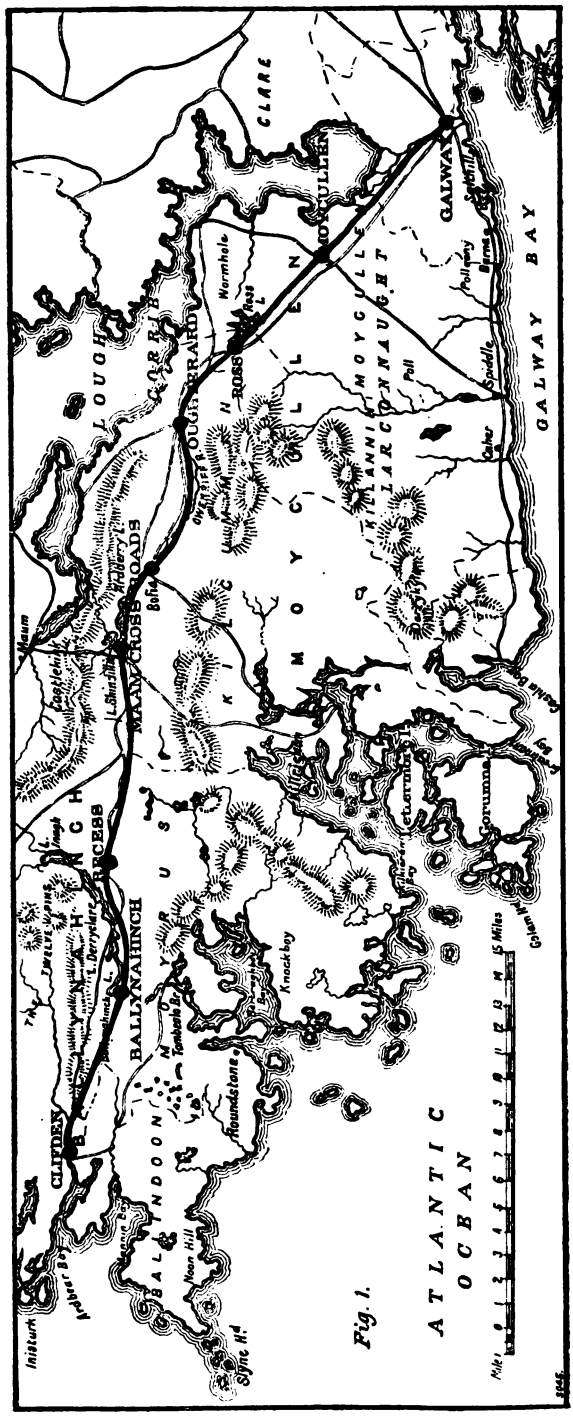
Fig. 16.



PLAN--CONSTRUCTION OF AUTHOR'S CURVED SLANTING GROYNES.

THE UTILIZATION OF SEWAGE.





MAP SHOWING ROUTE OF GALWAY AND CLIFDEN RAILWAY.

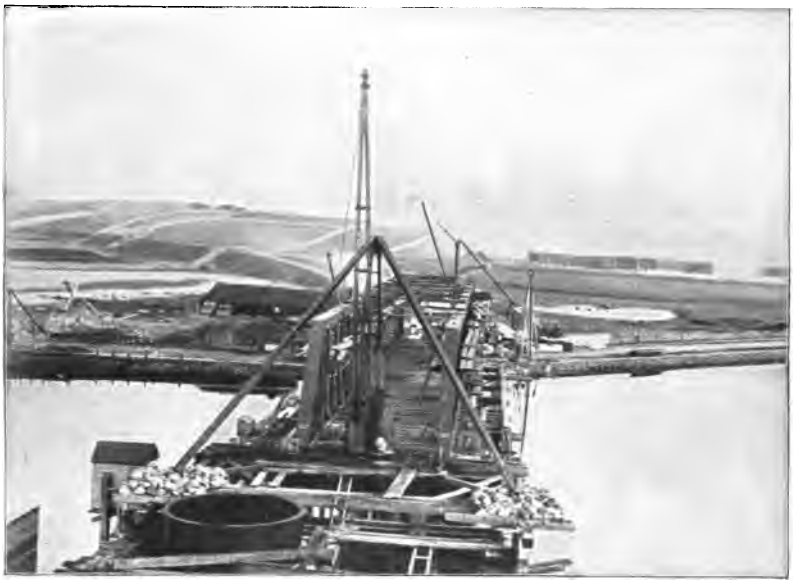
Fig. 1.

ROCK CUTTING, OUGHTERARD.

Fig. 2.

PROSPECT HILL TUNNEL.

Fig. 3.



CORRIB RIVER BRIDGE (IN PROGRESS).

Fig. 4.

CORRIB RIVER BRIDGE (IN PROGRESS).

Fig. 5.

CORRIB RIVER BRIDGE (IN PROGRESS).

Fig. 6.

CORRIB RIVER BRIDGE (IN PROGRESS).

Fig. 7.

CORRIB RIVER BRIDGE (ELEVATION).

Fig. 8.

CORRIB RIVER BRIDGE PERSPECTIVE VIEW).

FIG. 4. EARTHWORK